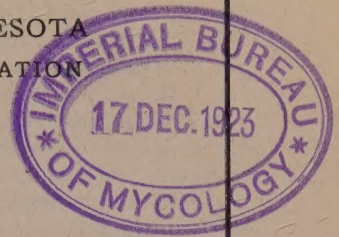


THE UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION



FRUIT AND VEGETABLE DISEASES

BY E. C. STAKMAN, J.G. LEACH, AND J. L. SEAL
DIVISION OF PLANT PATHOLOGY AND BOTANY



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* On leave of absence.

† Coöperating with the Office of Cereal Investigations, U. S. Dept. of Agr.

CONTENTS

| | Page |
|---|------|
| General control measures..... | 7 |
| Seed selection and disinfection..... | 7 |
| Crop rotation | 8 |
| Sanitation | 8 |
| Soil disinfection..... | 8 |
| Resistant varieties..... | 9 |
| Spraying | 10 |
| When to spray..... | 10 |
| With what to spray..... | 10 |
| How to spray..... | 12 |
| Cost of spraying..... | 13 |
| Dusting | 15 |
| Fungicides | 15 |
| Bordeaux mixture..... | 15 |
| Copper sulfate wash..... | 17 |
| Corrosive sublimate solution..... | 17 |
| Formaldehyde solution..... | 17 |
| Lime-sulfur, concentrated..... | 17 |
| Lime-sulfur, commercial..... | 18 |
| Commercial preparations..... | 18 |
| Resin-lye mixture..... | 18 |
| Potassium sulfide solution (Liver of sulfur)..... | 18 |
| Sticker | 19 |
| Dusts | 19 |
| Diseases | 20 |
| Apple | 20 |
| Crinkle | 20 |
| Scab | 20 |
| Fire blight..... | 22 |
| Rust | 28 |
| Powdery mildew..... | 28 |
| Bitter rot..... | 28 |
| Black rot..... | 30 |
| Sooty blotch and fly speck..... | 32 |
| Crown gall..... | 32 |
| Cankers | 33 |
| Scald | 34 |
| Internal break-down..... | 34 |
| Frost injury in storage..... | 35 |
| Jonathan spot rot..... | 35 |
| Storage rots..... | 36 |
| Asparagus | 36 |
| Rust | 36 |
| Bean | 37 |
| Anthracnose | 37 |
| Blight | 37 |
| Mosaic | 38 |
| Downy mildew..... | 38 |
| Rust | 39 |

| | Page |
|----------------------------------|------|
| Beet | 39 |
| Leaf spot..... | 39 |
| Cabbage | 39 |
| Black rot..... | 39 |
| Club root..... | 40 |
| Soft rot..... | 41 |
| Blackleg | 43 |
| Yellows; wilt; yellow sides..... | 43 |
| Downy mildew..... | 44 |
| Celery | 44 |
| Early blight, leaf spot..... | 44 |
| Late blight..... | 45 |
| Yellows | 45 |
| Cherry | 46 |
| Brown rot..... | 46 |
| Shot hole..... | 46 |
| Cucumber | 46 |
| Wilt | 46 |
| Mosaic, white pickle..... | 46 |
| Downy mildew..... | 48 |
| Powdery mildew..... | 48 |
| Scab | 48 |
| Anthracnose | 49 |
| Currant | 49 |
| Leaf spot..... | 49 |
| Powdery mildew..... | 49 |
| Rust | 50 |
| Cane blight..... | 50 |
| Ginseng | 50 |
| Blight | 50 |
| Gooseberry | 50 |
| Powdery Mildew..... | 50 |
| Leaf spot..... | 51 |
| Rust | 51 |
| Grape | 52 |
| Black rot..... | 52 |
| Downy mildew..... | 54 |
| Powdery mildew | 54 |
| Lettuce | 54 |
| Downy mildew..... | 54 |
| Gray mold..... | 54 |
| Drop | 54 |
| Muskmelon | 56 |
| Anthracnose | 56 |
| Leaf blight | 56 |
| Downy mildew..... | 56 |
| Wilt | 56 |
| Onion | 57 |
| Blight; downy mildew..... | 57 |

| | Page |
|-------------------------------------|------|
| Pea | 57 |
| Blight | 57 |
| Powdery mildew | 58 |
| Plum | 58 |
| Black knot..... | 58 |
| Brown rot..... | 59 |
| Plum pocket | 59 |
| Shot hole..... | 61 |
| Scab | 62 |
| Powdery mildew | 62 |
| Wood rot..... | 62 |
| Gummosis | 62 |
| Potato | 63 |
| Radish | 63 |
| Club root | 63 |
| White rust..... | 63 |
| Raspberry and blackberry..... | 63 |
| Anthracnose | 63 |
| Cane blight..... | 65 |
| Gray bark disease; spur blight..... | 65 |
| Rust | 65 |
| Leaf spot..... | 65 |
| Crown gall | 66 |
| Leaf curl..... | 67 |
| Yellows | 67 |
| Squash | 67 |
| Wilt | 67 |
| Strawberry | 68 |
| Leaf blight | 68 |
| Tomato | 69 |
| Leaf spot..... | 69 |
| Point rot; blossom end rot..... | 69 |
| Black rot; ripe rot..... | 69 |
| Leaf mold | 71 |
| Mosaic | 71 |
| Anthracnose | 71 |
| Turnip | 73 |
| Black rot..... | 73 |
| Soft rot..... | 73 |
| Club root..... | 73 |
| Watermelon | 73 |
| Anthracnose | 73 |
| Downy mildew..... | 73 |
| Wilt | 73 |
| Vegetable rots | 73 |
| Spraying calendar..... | 74 |

ILLUSTRATIONS

| | Page |
|--|------------|
| Field of cabbage affected with club root, | Title page |
| Fig. 1. Large power sprayer..... | 11 |
| Fig. 2. Traction sprayer..... | 12 |
| Fig. 3. Knapsack sprayer..... | 13 |
| Fig. 4. Wheelbarrow sprayer..... | 14 |
| Fig. 5. Small hand sprayer..... | 14 |
| Fig. 6. Apple scab..... | 21 |
| Fig. 7. Fire blight on young twigs..... | 22 |
| Fig. 8. Twig blight (fire blight) of apple..... | 23 |
| Fig. 9. Fire blight cankers..... | 25 |
| Fig. 10. Apple rust, summer stage, on leaves and fruit..... | 26 |
| Fig. 11. Apple rust, winter stage, on red cedar..... | 27 |
| Fig. 12. Coniothyrium canker on apple..... | 29 |
| Fig. 13. Black rot of apple..... | 29 |
| Fig. 14. Black rot canker on apple..... | 30 |
| Fig. 15. Wood rot of apple..... | 31 |
| Fig. 16. Sooty blotch and fly speck..... | 32 |
| Fig. 17. Crown gall on apple..... | 33 |
| Fig. 18. Jonathan spot rot..... | 35 |
| Fig. 19. Mosaic disease of bean..... | 38 |
| Fig. 20. Cabbage plants affected with club root, in field and pulled up..... | 40 & 41 |
| Fig. 21. Black leg of cabbage..... | 42 |
| Fig. 22. Cucumber wilt in greenhouse..... | 47 |
| Fig. 23. Cucumber mosaic on leaves..... | 47 |
| Fig. 24. Nectria canker on currant..... | 49 |
| Fig. 25. Black rot on grape..... | 51 |
| Fig. 26. Downy mildew on grape..... | 52 |
| Fig. 27. Mummied grapes caused by downy mildew..... | 53 |
| Fig. 28. Lettuce drop..... | 55 |
| Fig. 29. Black knot of plum..... | 58 |
| Fig. 30. Brown rot of plum..... | 60 |
| Fig. 31. Brown rot of plum, twig and blossom blight..... | 61 |
| Fig. 32. Plum pocket, bladder plums, fool's plums..... | 62 |
| Fig. 33. Wood rot on plum twigs..... | 63 |
| Fig. 34. Gray bark disease and anthracnose of raspberry..... | 64 |
| Fig. 35. Raspberry crown gall..... | 66 |
| Fig. 36. Strawberry leaf spot..... | 68 |
| Fig. 37. Tomato leaf spot..... | 70 |
| Fig. 38. Tomato mosaic disease..... | 72 |

FRUIT AND VEGETABLE DISEASES

BY E. C. STAKMAN, J. G. LEACH, AND J. L. SEAL

Fruit and vegetable diseases cause serious losses in Minnesota. Nearly every farmer has a vegetable garden and many homes have orchards. Diseases take too large an annual toll from these gardens and orchards. Both fruits and vegetables are grown very intensively in certain localities. It is well known that diseases and pests are likely to accumulate in those places unless definite measures are taken to prevent them.

The methods of control for some diseases are easy, and for others more difficult. However, by applying control measures that are now known, it is possible to save large sums of money annually. A brief discussion of general control measures therefore is given. This does not include all details, but merely calls attention to some of the general operations by which diseases can be controlled. Specific control measures are given under discussions of the various diseases.¹

GENERAL CONTROL MEASURES

SEED SELECTION AND DISINFECTION

Selection of seed or of nursery stock is often extremely important in preventing the development of disease. Many destructive disease organisms, such as those causing bean anthracnose, bean blight, black rot of cabbage, and bacterial wilt of sweet corn, may be carried on or in the seed. Seed disinfection will sometimes kill the disease germs on the seed; but sometimes it is impossible to rid the seeds of parasites in this way. Under such circumstances, it is necessary to select clean seed in the beginning. It is always well to consider the desirability of disinfecting vegetable seeds with formaldehyde or with corrosive sublimate. Many serious outbreaks of diseases would have been prevented if this precautionary measure had been taken.

The careful selection of nursery stock also will frequently reduce damage caused by diseases. Crown gall of raspberries and apples, fruit tree cankers, and other similar diseases are spread on nursery stock. Most Minnesota nurserymen are careful to sell only clean stock, but growers always should be sure to set out only healthy plants.

¹ For those who wish detailed publications, the following are suggested: Hesler and Whetzel, "Manual of fruit diseases." (Published by the Macmillan Co., New York) 1917.

Stevens and Hall, "Diseases of economic plants." Revised Ed. (Published by the Macmillan Co., New York) 1921.

Anderson, H. W., "Diseases of Illinois fruit." Ill. Agr. Exp. Sta. Circ. 241. 1920.

CROP ROTATION

Many of the parasites that cause vegetable diseases accumulate in the soil; consequently if the crop is grown in the same soil year after year, or if closely related crops are grown in successive years, these diseases are likely to become destructive. For instance, some of the most serious diseases of cabbage also attack cauliflower, brussels sprouts, rutabagas, and turnips. Therefore if club root, black rot, or similar diseases develop on any one of these crops, none of the others should be planted in the diseased soil the following year. Rotation of vegetable crops is not only desirable, but sometimes essential.

Bush and tree fruit crops can not be rotated as easily as vegetable crops, but even with these it is well to practice as much rotation as is possible. This is particularly true if such diseases as crown gall and root rot are present.

SANITATION

Sanitation is extremely important in controlling diseases. Most of the serious diseases of fruit and vegetable crops are caused by parasites which are spread rather easily from one plant to another, either by the wind, by insects, by water, or even by man. It always is well, therefore, promptly to destroy diseased plants or plant parts. A cankered apple tree branch should not be left on the tree as the source of infection of other branches. It should be cut out and burned as soon as it becomes diseased. In the same way, if cucumber wilt appears in the field, the wilted vines should immediately be pulled and destroyed. If they remain, insects are likely to spread the bacteria that cause the wilt, to neighboring plants.

In general, all diseased material should be destroyed. The refuse from a diseased crop should be kept off the land on which the same kind of crop will be grown the next year. The strictest sanitation will aid very materially in reducing losses from disease.

SOIL DISINFECTION

Sometimes it is necessary to disinfect the soil in seedbeds, cold frames, or greenhouse benches. Hot water, steam, or formaldehyde is used most often for this purpose.

Disinfection by hot water.—Pots, flats, etc., can be disinfected by keeping in water at 208 degrees, F., for five minutes. On shallow benches, boiling water poured over the soil at the rate of seven gallons per cubic foot kills most disease producing organisms.

Permanent steam disinfection.—In greenhouses, where the soil in the benches should be disinfected frequently, the following method is very useful:

Use several pipes that will extend the full length of the bench. Bore one-fourth inch holes every six inches along one side of the pipe. Lay them not more than eighteen inches apart, the side with holes down, and near the bottom of the bench. Then connect the pipes to the main steam pipe at one end of the bench. These pipes are permanent fixtures and should not interfere with the cultivating of the plants. Before the soil is to be steamed it should be well worked up and covered.

The Sargent method.—This method is similar to the above in principle and consists in constructing a form of harrow with perforated teeth. The teeth are forced into the ground and the main pipes connected to a boiler. Treat the soil at a temperature of 135 degrees, F. from forty-five minutes to an hour. The chief advantage of this method is that the harrow may be moved from place to place, but unless a portable boiler is on hand this method of soil treatment is out of the question.

Inverted pan method.—The equipment and treatment is similar to that of the Sargent method with the exception of a portable galvanized iron pan, say, 6 by 10 feet by 6 inches, which has sharpened edges so that the sides may be easily forced into the soil.

Disinfection by formaldehyde.—The soil should be dug up and thoroly prepared. Then wet it thoroly and let it stand from twelve to twenty-four hours so that all particles are wet. Apply the formaldehyde, 3 pints to 50 gallons of water, at the rate of one gallon to a square foot of soil. Burlap bags that have been wet with the formaldehyde solution should be spread over the treated soil for twenty-four hours in order to keep the formaldehyde fumes in the soil. The soil then should be well aired by stirring it every three or four days until two weeks have elapsed, when it may be prepared for planting.

Formaldehyde is the most effective of the chemical agents and costs about two cents per square yard of soil.

RESISTANT VARIETIES

Considerable progress has been made in reducing the losses from plant diseases by growing disease-resistant varieties. Unfortunately, not enough of these resistant varieties are known, and even when known, they sometimes are not the best for commercial purposes. Whenever possible, however, varieties resistant to a disease should be grown in regions where that disease is serious. Most Minnesota fruit growers know the apple rust, which often damages crab and Wealthy apples. But Duchess and the Greenings, as well as most of the other varieties of large apples commonly grown in Minnesota, are almost immune to rust. Therefore, if the disease is destructive in certain regions, its ravages could be overcome by planting Duchess, Greenings, or other resistant varieties instead of the susceptible crab and Wealthy apples.

SPRAYING

Many diseases can be prevented almost entirely by spraying. But in order to be effective spraying must be done at the right time, in the right way, and with the right materials.

WHEN TO SPRAY

No general statements applicable to all conditions can be made. The proper time for spraying depends on the disease, on its peculiarities in a given locality, and very largely on local conditions. Recommendations are given, where possible, in the text of the bulletin.

Weather conditions should always determine, at least to a certain extent, when the spray material should be applied. It must be remembered that spraying only protects plants from infection, and does not cure them after they are infected. For this reason it is much better to spray before a rain than after, because infection usually occurs during periods of wet weather. Whenever it is possible, therefore, to take advantage of weather reports, spraying should be done before general periods of rainy weather. If spray mixtures are allowed to dry on the plants for an hour or two, they usually will stick, even through heavy, driving rains.

WITH WHAT TO SPRAY

Any substance that kills a fungus is known as a fungicide. Various fungicides are used in spraying fruit trees and vegetables, the most common being lime-sulfur solution and bordeaux mixture. For spraying apples and plums, commercial lime-sulfur solution has now displaced bordeaux mixture to a large extent in Minnesota, because of its convenience. It is merely necessary to dilute it with water. It is very effective against such diseases as apple scab and brown rot of plum. However, bordeaux mixture is considered more effective than lime-sulfur against such diseases as downy mildew of grape, tomato leaf spot, bitter rot and black rot of apple. Spray injury may sometimes result from either mixture, but bordeaux is probably more likely to cause injury than lime-sulfur, especially on fruit. There should be no very great difference in the cost of the two, altho exorbitant prices are sometimes charged for lime-sulfur. When this is the case, it is advisable either to substitute bordeaux mixture or to make lime-sulfur at home.

Other materials, too, are used as fungicides for certain diseases. For instance, potassium sulfide is considered especially effective against such diseases as the powdery mildews. There also are several patent fungicides on the market, some of which are advertised as being both fungicides and insecticides. Some of these have been tried at the Minnesota station, but as a rule they are no cheaper than the standard fungicides and give no better results.

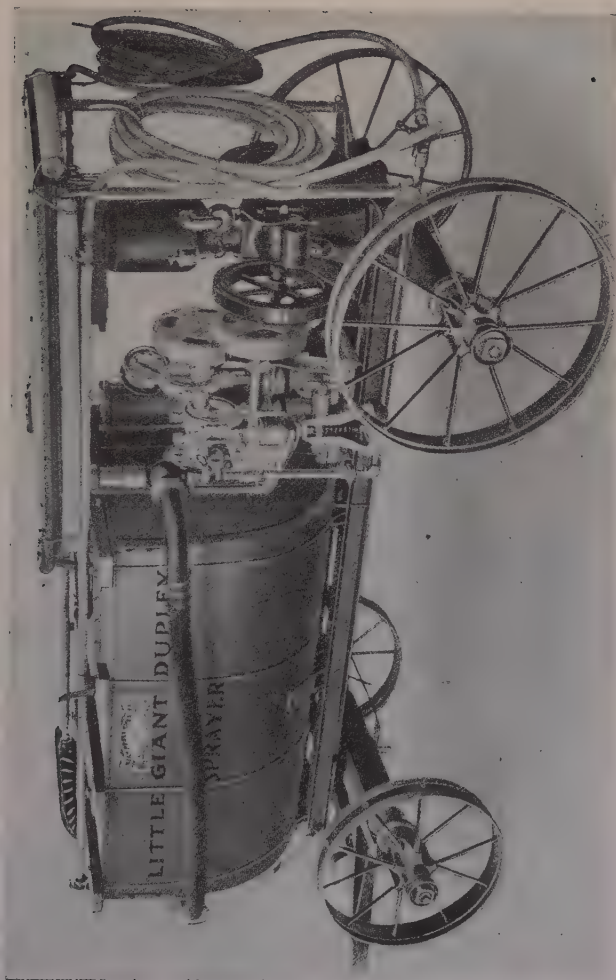


Fig. 1. Large Power Sprayer
This is a good type for a large orchard.

Often there are insect pests as well as fungus pests to be controlled. Combination sprays should be applied whenever both are needed. The most common combination in orchard and garden work is arsenate of lead with either bordeaux mixture or lime-sulfur. The general spraying schedule, together with the combination spray, will be found in the spray calendar on pages 74 and 75.

HOW TO SPRAY

A great deal depends on the thoroughness of the spraying. In order to spray thoroly, a good machine must be used. The size and type of machine will vary with the kind and amount of work to be done. For a large orchard, a power sprayer or a good barrel pump which can be carried on a wagon should be used. There are also small gasoline engines attached to barrel pumps which cost from \$100 to \$125.

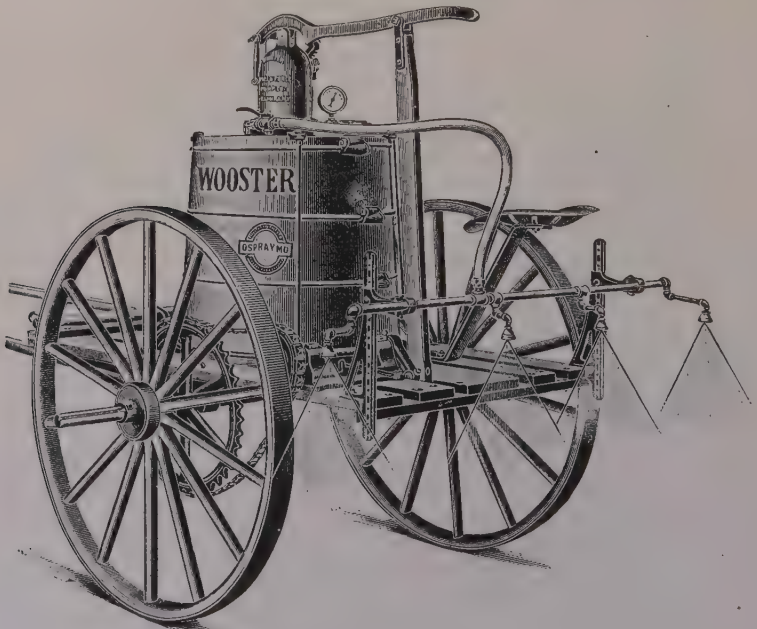


Fig. 2. Traction Sprayer

This type of sprayer may be purchased with power attachments and when so equipped is more efficient and better for a large acreage. It is suitable to use for potatoes and truck crops.

A small outfit can be bought for from \$30 to \$40. Sprayers suitable for small gardens or bush fruits can be purchased for still less. One of the greatest essentials in all machines is a good pump, one that is durable and with which it is possible to maintain a high and constant pressure. With a high-pressure tank it is possible to maintain a pressure of 200 pounds or more with a hand pump. The average orchardist

or gardener in Minnesota does not use enough pressure; at least 200 pounds should be used when trees are being sprayed. This is both economical and effective. The reason for it is simple. When the spray material is applied under high pressure it is blown out in very fine drops and the plant parts can be covered very quickly without drenching. In this way material is saved. When low pressure is used, necessitating the use of a greater amount of the material, the spray material often collects along the margins and veins of leaves and causes spray injury. All parts of the plant should be covered uniformly. It is only in this way that protection against infection is assured. To get the best results a good type of nozzle also is necessary. In general, any type of nozzle which gives a good, fine spray will be effective if sufficient pressure is used.

Caution: Never spray trees when in full bloom; it is not necessary and may injure bees.

COST OF SPRAYING

Several items enter into the cost of spraying. These can be summed up as follows: (1) Location of the grower with respect to the manufacturer of spray materials; (2) materials used; (3) type of machinery used; (4) convenience in preparation and application.

A grower at a considerable distance from the manufacturer may have to pay more for his material than one who is nearer. This added cost can be reduced if several growers coöperate and buy the materials



Fig. 3. Knapsack Sprayer

This is a very convenient size for a small acreage. The tank holds about three gallons.

in large quantities. Bluestone, in 100-pound lots, usually costs from 7 to 10 cents a pound. Commercial lime-sulfur costs 20 or 25 cents a gallon in 50-gallon barrels. Powdered sulfur in barrel lots costs from 5 to 6 cents a pound, and stone lime usually costs less than 2 cents.

An important consideration is the convenience with which the spray materials can be mixed. This involves the location of the mixing tanks in relation to the orchard and the source of the water supply, and also the kind of mixing tanks used, consideration being given to the ease and quickness with which the sprayer can be filled. The greater the convenience with which these things can be done, the smaller will be the cost of labor.

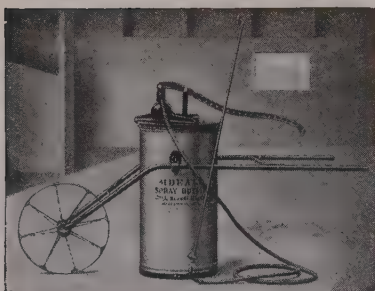


Fig. 4. Wheelbarrow Sprayer

This is a good type for a moderate acreage. The tank has a capacity of about ten gallons.

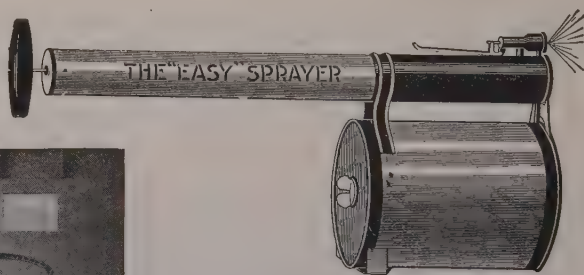


Fig. 5. Small Hand Sprayer

This size is well suited for the home garden.

Experiments at the Minnesota Agricultural Experiment Station and in coöperation with some of the fruit growers have been carried on with a view to determining the actual cost of spraying with different fungicides. The results have shown only a small difference between the cost of the bordeaux mixture and the different lime-sulfur sprays. The average cost of spraying large apple trees four times varies from 18 to 25 cents a tree. This includes cost of materials, labor, and depreciation of machinery.

There is always a question as to whether or not it pays to spray. The following figures, based on 100 trees per acre, were obtained from careful records kept for several years on the value of spraying apples:

| | Average yield Bushels | Marketable fruit, No. 1 Bushels |
|-----------------------|--------------------------|------------------------------------|
| Sprayed fruit | 375 | 282 |
| Unsprayed fruit | 300 | 144 |
| Difference..... | 75 | 138 |

At 50 cents a bushel there is a difference of \$69 an acre in favor of the sprayed trees. After deducting \$17.60, the average cost of spraying, a net increase of \$51.40 an acre remains.

DUSTING

In the last few years extensive experiments have been carried on, especially in the fruit growing regions of the East, to find out whether dust could be substituted for liquid spray. A very finely powdered sulfur has been used most commonly. While the results are somewhat conflicting, the evidence seems to be that diseases in most regions are controlled practically as well by dusting as by spraying. Similar experiments have been made in Minnesota for the last three years with promising results. When the effect of dust was compared with that of bordeaux mixture and lime sulfur, the results were approximately the same. All three of the fungicides controlled apple scab fairly well when they were applied at the right time and in the right way.

The advantages of dusting are quite obvious. The dust can be applied much more quickly than the spray, and the labor involved is not so great. Furthermore, dusting is scarcely more unpleasant work than spraying. The writers are quite confident that dusting when properly done, will give good results. However, it is not recommended as being preferable to spraying. In large orchards it has very distinct advantages; in smaller orchards the advantages are less distinct.

Anyone contemplating dusting is invited to correspond with the experiment station regarding the most satisfactory machinery and materials.

FUNGICIDES

BORDEAUX MIXTURE

Copper sulfate, 4 pounds
Quicklime, 4 pounds
Water, 50 gallons

Bordeaux mixture is made from copper sulfate (bluestone), quicklime, and water. It is used in various strengths, 4-4-50 probably being used most commonly. Four-four-fifty simply means that 4 pounds of copper sulfate, 4 pounds of lime, and 50 gallons of water are used in the preparation of the mixture; and 2-2-50 means that 2 pounds of copper sulfate, 2 pounds of lime, and 50 gallons of water are used. The num-

ber of pounds of copper sulfate is indicated by the first figure, the number of pounds of lime by the second, and the number of gallons of water by the third.

Bordeaux mixture may be made for immediate use, or a stock solution may be made and diluted when it is needed. In making the spray for immediate use, put 4 pounds of copper sulfate into a cloth sack and hang it in a barrel containing 25 gallons of water. Being suspended, the copper sulfate will dissolve much more readily than if it were resting on the bottom of the barrel. It dissolves more quickly in hot than in cold water. Now slake carefully 4 pounds of the best quicklime available, using just enough water to slake it slowly. When the lime is slaked, add enough water to make 25 gallons. Stir it carefully and then pour together the copper sulfate solution and the milk of lime, so that the streams mix in pouring. A slight excess of lime is desirable, as it prevents any injurious action of the copper salts. There will always be an excess if the lime is of good quality. If there is an excess of copper, the foliage may be injured. Simple tests may be made to determine whether or not the mixture is safe to use. Put a piece of newly filed iron or steel into the mixture for about a minute. If it has a copper coating when it is taken out, there is an excess of copper, and more lime should be added. To determine whether or not there is enough lime in the mixture, pour some of it into a flat dish and blow on it for a few moments. If a film forms on the surface, there is enough lime, if not, more should be added. If the mixture is alkaline it is perfectly safe. This can be determined by the use of litmus paper which can be obtained at drug stores with directions for its use. Bordeaux mixture should be used the same day it is made. If it is necessary to keep it for a day or two, add 2 ounces of cane sugar to each 50 gallons of the mixture.

In making stock solutions, dissolve copper sulfate in water at the rate of 1 pound to 1 gallon of water. Slake the lime slowly in another vessel, and, when slaked, add water until a thick lime milk, 1 pound to 1 gallon of water, is formed. When using the stock solution in making up the spray mixture, 1 gallon of copper sulfate solution represents 1 pound of copper sulfate, and 1 gallon of lime water represents a like amount of lime—more or less—depending on the quantity of water used in making the stock solution. The stock solutions should be diluted separately before they are poured together. The stock solution of lime should be run through a fine-mesh sieve in order to remove all lumps which might clog the nozzle of the sprayer. Stock solutions can be kept indefinitely.

COPPER SULFATE WASH

Copper sulfate, 3 pounds
Water, 50 gallons

Copper sulfate is sometimes used as a wash on dormant trees. It should never be used on trees after the buds have opened.

CORROSIVE SUBLIMATE SOLUTION

Mercury bichloride (corrosive sublimate), 2 ounces
Water, 15 gallons

Corrosive sublimate solution is extremely poisonous when taken internally, and should be handled with great care. It is not injurious to the skin, however. It is very effective in treating seeds and is used for disinfecting pruning instruments when cutting out fire blight or cankers. It should not be put in metal vessels, as it may corrode them.

FORMALDEHYDE SOLUTION

Formaldehyde (40 per cent), $\frac{1}{2}$ pint
Water, 15 gallons

Formaldehyde solution is used in treating seeds.

LIME-SULFUR, CONCENTRATED

Concentrated lime-sulfur may be bought already prepared or it may be made at home. When made at home it is necessary to have a Baumé hydrometer to determine the density of the material. The following directions for making it, and the table of dilutions, are taken from New York (Geneva) Bulletin 329.²

Lime (pure lime, CaO, used as basis), 36 pounds
Sulfur, high-grade, finely divided, 80 pounds
Water 50 gallons

When lime containing impurities is used, more than 36 pounds must be used in order to obtain 36 pounds of pure lime. (Use 40 pounds of lime containing 10 per cent of impurities, i.e., 90 per cent pure.)

Make a paste of the sulfur with about 10 gallons of hot water. Add the lime. As the lime slakes add hot water as necessary to prevent caking. When the lime has slaked add hot water to make 50 gallons and boil for one hour. Stir the mixture constantly, especially the sediment in the bottom of the kettle. Add water frequently during the boiling so as to keep the level of the mixture near the 50-gallon mark. Store in air-tight, hardwood barrels.

When ready for use, test the concentrate with a Baumé hydrometer and dilute according to the following table:

² Van Slyke, L. L., Bosworth, A. W., and Hedges, C. C. "Chemical investigation of best conditions for making the lime-sulfur wash." N. Y. Agr. Exp. Sta. (Geneva) Bul. 329. 1919.

| Concentrate testing | Dormant spray | Apple summer spray | Cherry and plum summer spray |
|---------------------|---------------|--------------------|------------------------------|
| Degrees (Baumé) | | | |
| 35 | I-16½ | I-43½ | I-56 |
| 34 | I-16 | I-42½ | I-54 |
| 33 | I-15½ | I-41 | I-52 |
| 32 | I-15 | I-40 | I-50 |
| 31 | I-14½ | I-39 | I-48 |
| 30 | I-14 | I-37½ | I-46 |
| 29 | I-13½ | I-36 | I-44 |
| 28 | I-13 | I-35 | I-42 |
| 27 | I-12½ | I-33½ | I-40½ |
| 26 | I-12 | I-32½ | I-38½ |
| 25 | I-11 | I-31 | I-37 |

Arsenate of lead may be added to the diluted concentrate at the rate of from 2 to 3 pounds to 50 gallons. Do not use paris green, arsenite of lime, or arsenite of soda with lime-sulfur.

LIME-SULFUR, COMMERCIAL

| | | |
|--------------|--------------|------------|
| Dormant wash | Lime-sulfur, | 1 gallon |
| | Water, | 9 gallons |
| Summer spray | Lime-sulfur, | 1 gallon |
| | Water, | 40 gallons |

Commercial lime-sulfur is a manufactured preparation and may be used according to the above formulas instead of the homemade preparations. It has the advantages of being ready for use and of not clogging the nozzles.

POTASSIUM SULFIDE SOLUTION (LIVER OF SULFUR)

| | |
|--------------------|---------------|
| Potassium sulfide, | 3 to 5 ounces |
| Water, | 10 gallons |

Potassium sulfide solution is considered especially effective against powdery mildews, such as gooseberry mildew. It also is used quite extensively in greenhouses and on shrubbery.

COMMERCIAL PREPARATIONS

All available information concerning commercial preparations may be obtained by application to the Section of Plant Pathology, University Farm, St. Paul, Minnesota.

RESIN-LYE MIXTURE

The resin-lye mixture is often used in combination with a fungicide or an insecticide to insure the sticking of the necessary poisonous material to smooth, glossy leaves. The formula is:

| | |
|---------------------------|-----------|
| Pulverized resin, | 5 pounds |
| Concentrated lye, | 1 pound |
| Fish or other animal oil, | 1 pint |
| Water, | 5 gallons |

Put the oil, the resin, and 1 gallon of the water in an iron kettle and heat until the resin softens; then add the lye and stir thoroly. Add to this 4 gallons of hot water, and boil until a little of the boiled material mixed with cold water gives a clear, amber-colored liquid. Add water to make 5 gallons.

This is the stock solution. In spraying with paris green or bordeaux mixture, add 2 gallons of this mixture to 8 gallons of water and add to 40 gallons of the spray mixture. The spray mixture to which this is added should be made with 10 gallons less water than the formula indicates, because this will be added with the resin-lye mixture.

STICKER

On some plants spray materials do not spread well and consequently do not stick. The adhesiveness and spreading qualities of a spray mixture can be increased by the addition of resin-lye mixture. Directions for making are given under "Resin-lye Mixture."

Fish oil soap serves the same purpose and is much more convenient for use. About 2 pounds of resin-fish oil soap should be added to 50 gallons of spray material. This is especially valuable when spraying asparagus, raspberries, tomatoes, plums, and other plants with smooth fruit or foliage.

DUSTS

Dusting on a large scale has been developed only recently. Very good results have been obtained in different localities in controlling apple scab and apple insects. The dust mixtures are slightly more expensive than the liquid sprays, but the ease with which they can be applied counteracts the difference in price. The dust should be applied early in the morning while the dew is heavy on the fruits and leaves.

Sulfur.—Flowers of sulfur (ordinary powdered sulfur) is often dusted on plants to prevent such diseases as the powdery mildews.

Sulfur dust.—Sulfur dust, commonly known as "Cornell Mixture No. 2," has 85 per cent ground sulfur and 15 per cent arsenate of lead. Dusting experiments conducted here for the last three years with this mixture have not given quite as effective control of apple scab as the liquids, but nevertheless they were very satisfactory.

Copper dust.—Copper dust was first used by G. E. Sanders of Nova Scotia, Canada, where it was found to be very effective in the control of apple scab and late blight of potato. The dust is composed of a mixture of powdered anhydrous copper sulfate and hydrated lime. Calcium arsenate also is usually included for the control of biting insects. Preliminary experiments have been made with copper dust in Minnesota, but, while the results have been encouraging, more work is necessary before it can be recommended as a substitute for bordeaux mixture.

DISEASES

APPLE

Crinkle

Crinkle is a physiological disease which appears chiefly on the Northwestern Greening. It is very similar to bitter pit except that the pits are larger and are confined to the blossom end of the fruit. It may occur early in the season, while the other fruit spots of this type occur only late in the season. The outward appearance of the disease is sunken spots over which the skin may show very little, if any, difference in color from normal skin, but later in the season the skin over the spots usually dies and turns dark, forming a complete dead area around the calyx end.

When a transverse cut is made through one of these spots the tissue beneath the skin is seen to be brown and spongy, with large cavities throughout, while the skin itself remains intact.

This disease seems to be confined chiefly to the portion of the fruit farthest from the water ducts and to be due to a sudden checking of the water supply during the early growing season.

Scab. (*Venturia inaequalis*)

Scab affects the flower pedicels, leaves, fruit, and sometimes the young twigs. It is most conspicuous on the leaves and fruit. On the leaves the scab spots are usually dark and velvety or sooty. The leaf may be almost completely covered. The spots on the fruit at first resemble those on the leaves. Later large scabby spots may be formed. The fruit may crack and is often badly deformed. When the disease begins early in the season, it may attack the flower pedicels so severely as to cause many flowers to drop.

The scab fungus lives over winter mainly in the scabby leaves that have fallen to the ground. If possible, therefore, plow fallen leaves under either in the fall or early in the spring.

Some varieties are extremely susceptible while others are quite resistant. Most of the crab apples and Lubsk Queen are very susceptible, while Pattens Greening and Northwestern Greening are apparently most resistant. In fact the Greenings, particularly the Northwestern Greening, seem to be resistant to the three most serious apple diseases in Minnesota: scab, rust, and fire blight.

Scab can be controlled almost entirely by proper spraying. Spray first just before the flower buds open; second, when the petals are falling; and third, about three weeks after the second spraying. A fourth spraying may be necessary if the weather is favorable for the development of scab late in the season. If, as is often the case, a serious infection occurs early in August, a fourth spraying certainly pays. Watch the leaves carefully and just as soon as the first scab spots begin to ap-

pear, spray very thoroly. The necessity for spraying depends largely on seasonal conditions. Scab develops most rapidly in moist, cool weather; and less rapidly in hot, dry weather. It often is possible to control the disease, therefore, by spraying only once or twice. It is safest, however, to spray at least three times every year, and the fourth time if necessary.

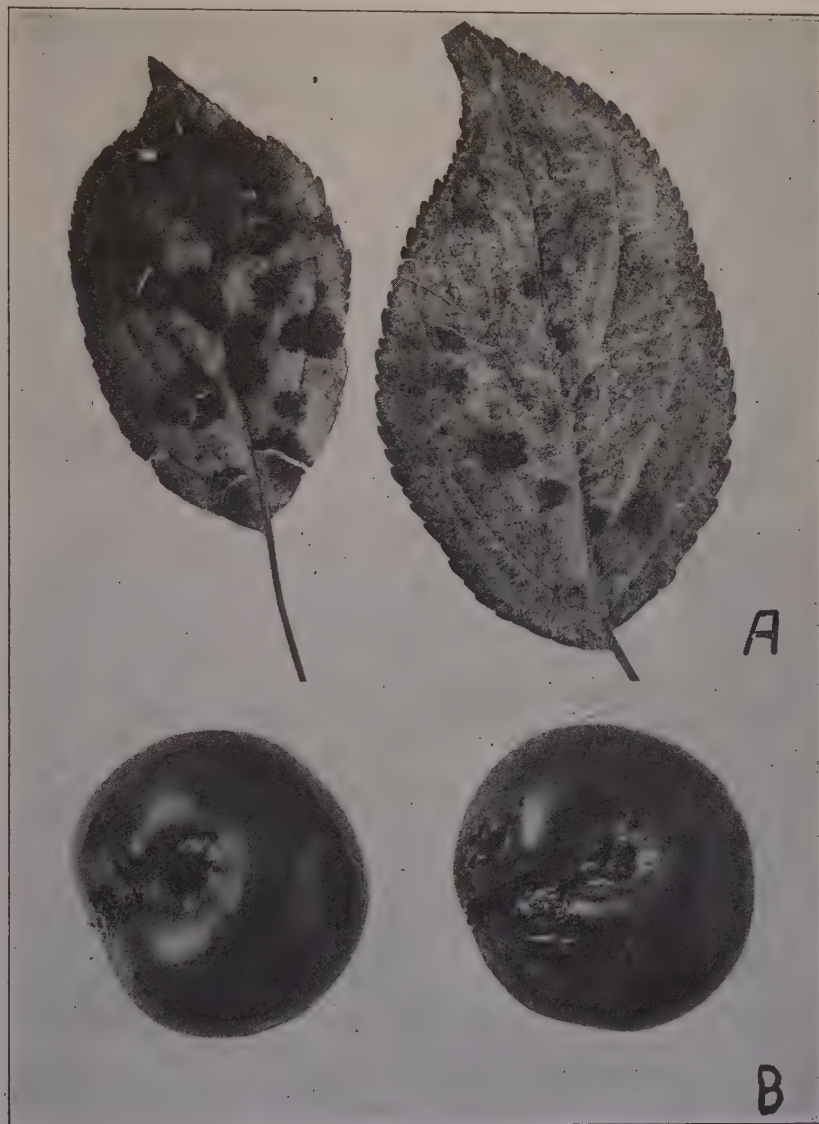


Fig. 6. Apple Scab

Scab causes olive-green felty patches on leaves, fruit, and twigs; and may cause fruit to crack as shown in B. It can be controlled by thoro spraying.

Both commercial lime-sulfur and bordeaux mixture are effective in controlling scab when they are properly applied (see section in introduction on "How to Spray").

Bordeaux mixture seems to be slightly more effective, but lime-sulfur is so easy to prepare that in Minnesota it has almost entirely replaced bordeaux mixture. If bordeaux mixture is used the 4-4-50 formula will be found satisfactory. Commercial lime-sulfur should be used at the rate of about $1\frac{1}{4}$ gallons to 50 gallons of water. Dust preparations also have been effective in experiments made during the last four years in this state.



Fig. 7. Fire Blight on Young Twigs

Fire Blight (*Bacillus amylovorus*)

Fire blight is caused by a bacterial parasite which affects the blossoms, young fruit, leaves, twigs, branches, and even the trunks of apple trees. The disease is most conspicuous on the twigs and smaller

branches. Young twigs may be killed very quickly. The leaves suddenly become brown and the twig itself becomes black. The entire twig may be somewhat gummy, and the dead leaves remain on the tree for some time. Often so many of the twigs are killed in such a short time that the tree appears to have been scorched. Fruit spurs, suckers, and water sprouts may be attacked in the same way as the twigs.

The disease also may cause cankers on the larger branches and on the trunk. These cankers may spread very rapidly under favorable conditions, girdling and finally killing the branches. When cankers are formed on the trunks of small trees the entire tree may be killed. The cankers may be sunken slightly and nearly always are very dark brown or black in color. While the cankers are spreading the bark is often sticky or gummy, and drops of gummy liquid actually may be exuded. When the canker stops spreading the diseased tissue apparently shrinks, so that a ridge or crack develops all along the edge of the canker. (See Fig. 9.)

The bacteria in most of the cankers are killed during the winter, or, possibly, during unfavorable conditions in summer. However, in a few of the cankers the bacteria remain alive until the following spring. When the weather becomes favorable for the multiplication of the bacteria the canker again spreads and the milky liquid is exuded. This attracts insects which then carry the infective material to other plants or to other parts of the same plant, thus causing new infections.



Fig. 8. Twig Blight (fire blight) of Apple
Note dead leaves, dead wood, and dead, shrunk fruit.

The honey bee has been considered the most common carrier, but it has been shown within the last few years that at least a dozen different insects may carry the germs and cause infection. Plant lice sometimes are responsible for a very serious type of infection in Minnesota. They often puncture the young leaves and the young twigs after they have accumulated the bacteria on various parts of their body. In this way the blight starts on so many leaves and twigs that it is practically impossible to control it unless the plant lice are killed.

The rapidity with which blight spreads depends to a considerable extent upon the weather and the condition of the trees as well as upon the varieties grown. Blight is likely to be most destructive during periods of warm, moist weather. It may spread with amazing rapidity at such times. Just as soon as the weather becomes hot and dry, however, the disease may be checked very suddenly.

Blight may be especially destructive on trees that are growing rapidly. In general, therefore, anything which causes excessive growth should be avoided. Too much fertilizer and excessive pruning are likely to cause the development of many suckers, water sprouts, and tender twigs, which are especially susceptible to blight, and the disease spreads very rapidly in these tender tissues. In seasons when blight is serious, therefore, it may be advisable to put in a cover crop in order to check excessively rapid growth.

There is a great deal of difference in varietal susceptibility to fire blight. Transcendent and Virginia crab and Wealthy appear to be most susceptible in Minnesota. Duchess is seldom severely injured, while Pattens Greening and Northwestern Greening are so resistant that they are almost never affected.

The only methods of controlling fire blight are to avoid excessive pruning, over-fertilization, and excessive cultivation; to control insects; and to cut out the blight whenever it appears. Suckers and water sprouts should be cut from the trees. Moderate fertilization, judicious cultivation and pruning, and the intelligent use of cover crops will do much to prevent the destructive ravages of blight. In spite of these precautions, however, the disease is likely to become established unless insects are controlled, and unless proper sanitary precautions are taken.

The control of insects is extremely important in controlling fire blight. The addition of arsenate of lead to the lime sulfur or bordeaux mixture with which the trees are sprayed will help to control biting insects. Black leaf 40, or some other good contact insecticide, should be used to kill plant lice in seasons when they are abundant.

Diseased material should be cut out whenever it appears. If twig blight develops, the affected twigs should be cut off some distance back of the point to which the blight seems to have progressed. This work

must be done carefully and intelligently. It is very important to remember that there are countless numbers of bacteria in the diseased tissues. Unless the work is carefully done the pruning is likely to result in spreading the disease instead of eliminating it. The pruning knife should be kept sterilized. This can be done by swabbing it with a cloth



Fig. 9. Fire Blight Cankers Caused by Infection of the Young Fruit Spurs at X. Such cankers should be cut off and burned. Borders of the cankers are shown by lines.

soaked in a 1 to 1000 solution of corrosive sublimate. If blossom blight has become very prevalent it is almost impossible to cut out all the diseased portions of the tree. Cankers should be cut out. After they have been cut out the wound should be washed in the above mentioned corrosive sublimate solution. Large wounds should be painted over with coal tar or asphaltum. Small ones will callus over and thus protect the wound.

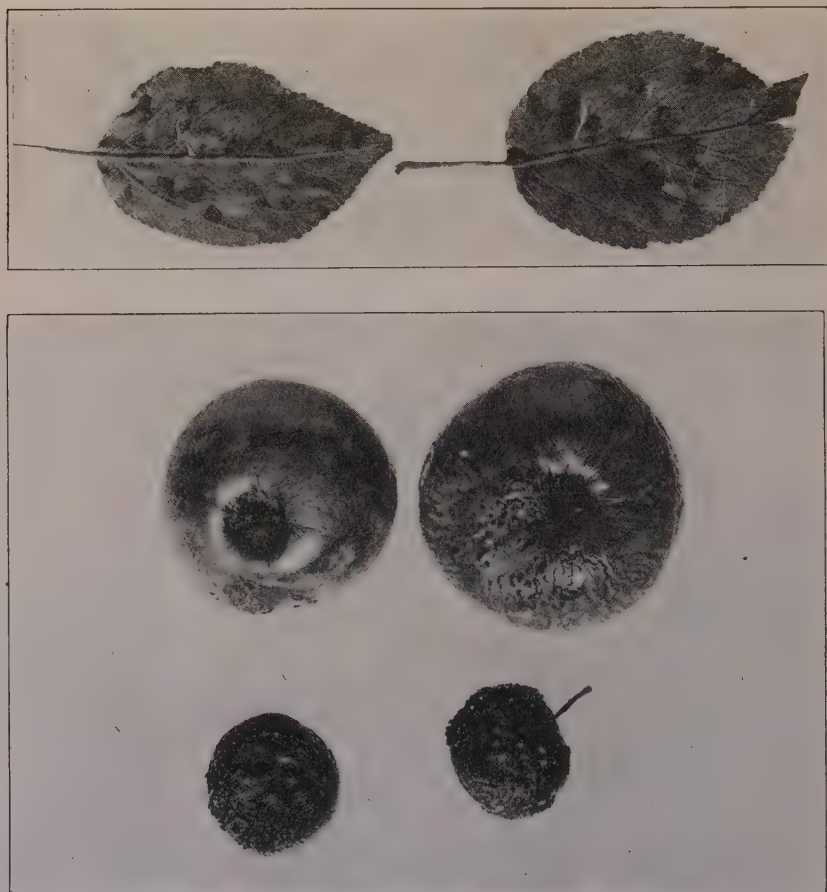


Fig. 10. Apple Rust, Summer Stage, on Leaves and Fruit

Unfortunately many Minnesota orchardists do not attempt to cut fire blight out of an orchard. The damage does not consist alone in the killing of the twigs and branches by the blight bacterium, but also in the fact that the wood killed by the blight is very likely to become infected with canker fungi and later with wood-rotting fungi. The effects of an epidemic of fire blight may therefore last for several years. Trees

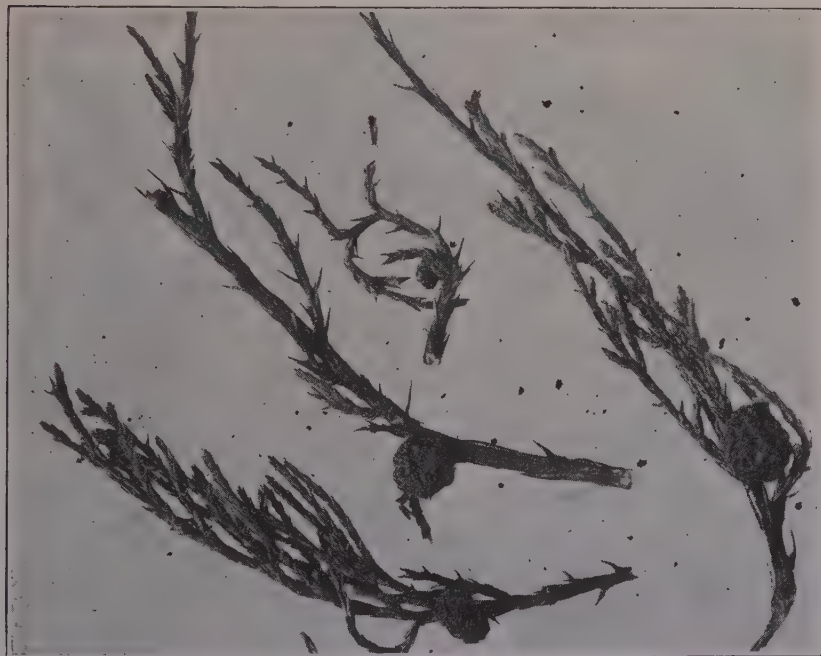
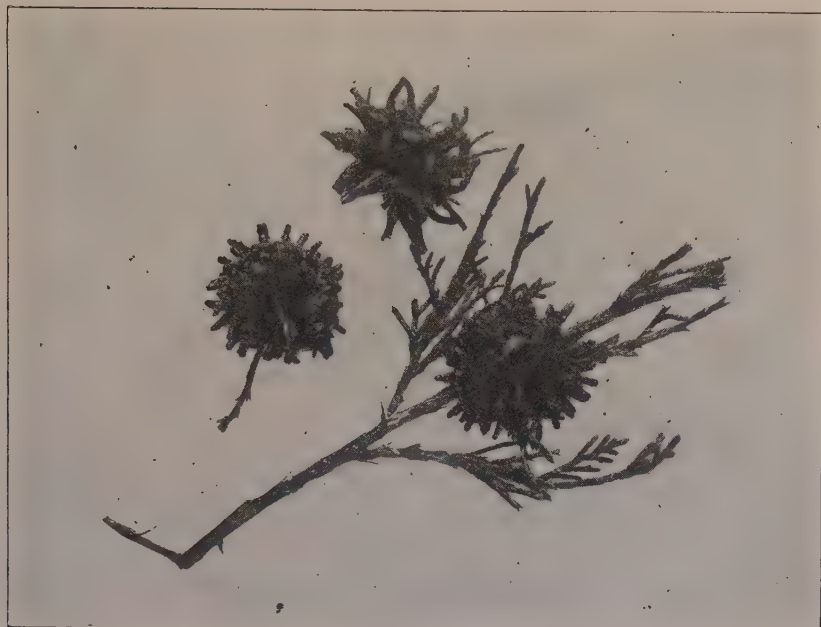


Fig. 11. Apple Rust, Winter Stage, on Red Cedar

Above, gelatinizing; below, non-gelatinizing. In the spring millions of spores are produced on these cedar apples and blow from these to the apple leaves and young fruit. Rust can be controlled by cutting out the cedars.

that have been badly affected may die two or three years after the blight appeared. Black rot canker very often follows blight and various wood rots follow the canker, hence every possible precaution should be taken to keep blight out of the orchard.

Rust (*Gymnosporangium juniperi-virginianae*)

Rust is most common on apple leaves altho it may also attack the fruit. Small, sticky, honey-colored spots are produced on the upper surface of the leaves. Later, orange-colored spots sometimes surrounded by a red margin are produced on the lower surface. The spots on the under surface are the cluster cups of the rust. If they are examined carefully, many little cup-like structures with a fringed border will be noticed. This stage of the disease usually appears late in June or early in July. If trees are badly infected they have a rusty appearance which can be seen from a considerable distance. The spores of the fungus which are produced in the cluster cups are blown to red cedars on which they produce the so-called cedar galls or cedar apples. The fungus over-winters on the red cedars. In the spring these cedar galls gelatinize during wet weather. (See Fig. 11.) The disease then spreads from the red cedar to the apple. Apple rust, therefore, can not live without red cedar trees.

The disease can be prevented by cutting out red cedars from the immediate neighborhood of the orchard. In fact, this is the only sure method of controlling the disease. Thoro spraying early in the season may check the development of the rust somewhat, but it can not be relied on to prevent it. If red cedars are near a valuable orchard in which there are susceptible varieties, the cedars should be cut out.

Many of the crab apples are very susceptible to rust. Of the large apples commonly grown in Minnesota, only the Wealthy is very subject to rust. Duchess and the Greenings are practically immune. Even when they are growing beside red cedar hedges they are not injured by rust.

Powdery Mildew (*Podosphaera oxycanthae*)

Powdery mildew seldom occurs on apple trees in this state, except on nursery stock. The mildew can be recognized by the dirty grayish appearance of the leaves. When the leaves are badly infected they may fall from the tree. The disease can be controlled by thoro spraying. The first application should be made when the leaf buds begin to open, and the leaves should be kept covered with the spray material.

Bitter Rot (*Glomerella cingulata*)

Bitter rot is not common in Minnesota. On the fruit it appears first as small, brownish patches beneath the skin. These rapidly enlarge



Fig. 12. Coniothyrium Canker on Apple

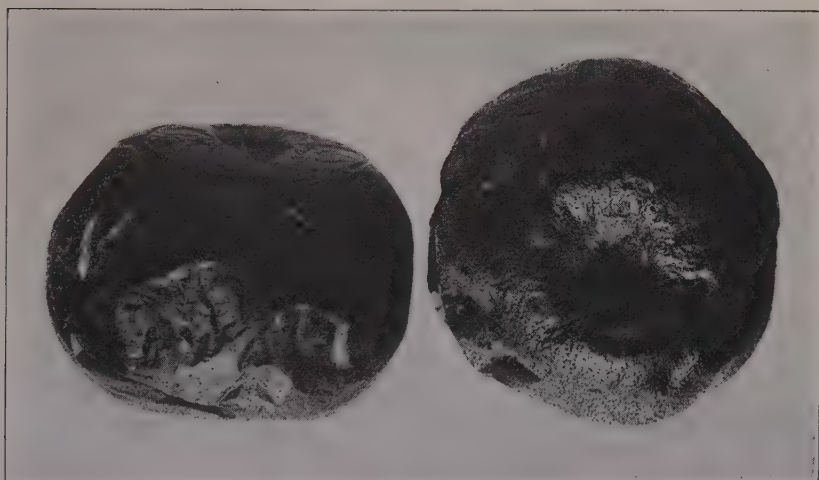


Fig. 13. Black Rot of Apple

Note the small black eruptions over the entire surface. These are the fruiting bodies of the fungus and serve as a source of infection to healthy fruit. Black rot is also produced on the twigs.

until they are of considerable size, when they form sunken, often wrinkled, areas, which may be corky and bitter around the edges. Often, in later stages, spore masses, usually arranged in concentric circles appear. The color is first pink; later, gray; and finally, very dark. The fruit is especially liable to attack while it is ripening but it may become infected earlier. Warm, damp weather is very favorable to the rapid spread of the disease.

On the branches cankers are formed. They are usually round or somewhat elongated spots, sometimes several inches long. The bark becomes very dry, cracks, and causes a characteristic sunken, wrinkled appearance. The disease probably persists largely in these cankers and also on the "mummied" fruit.

All rotten apples should be destroyed, and the cankered twigs should be pruned out. This, together with spraying, will control the disease, since it is usually not very serious in Minnesota. Spray frequently with bordeaux mixture 4-4-50 or with lime sulfur 1-40, beginning shortly after the petals fall and continuing at intervals until the fruit is practically mature.

Black Rot (*Physalospora cydoniae*)

Black rot attacks the fruit, the twigs, and the leaves. On the fruit it closely resembles bitter rot, especially in the earlier stages, altho the diseased areas are usually darker than those formed by bitter rot. The



Fig. 14. Black Rot Canker on Apple

Note the numerous small, pimple-like bodies. These produce millions of spores which are blown to healthy trees, causing infection on them.

color becomes darker until eventually the apple dries out, leaving only a black, much shrunk and shriveled, mummied fruit. Beneath the skin many small black eruptions may appear. The woody parts of the plant also may be affected. The fungus often gains entrance through wounds and causes cankers which may girdle limbs. It is very likely to follow fire blight.

Treatment consists in carefully pruning out all cankered areas and in destroying all mummied fruit, cleansing thoroly with a lime-sulfur wash during the dormant season, and careful spraying.

Bordeaux mixture is said to be more effective than lime-sulfur in controlling the disease. In Minnesota careful pruning, such as should always be practiced, together with the spraying for scab usually controls the disease.



Fig. 15. Wood Rot of Apple

Wood rot often follows fire blight and other injuries.

Sooty Blotch and Fly Speck (*Leptothyrium pomi*)

It is probable that sooty blotch and fly speck are caused by the same fungus. The sooty blotch, as the name indicates, is characterized by a dark greenish or black growth on the surface of the apple. Sometimes the spots are very small and are arranged more or less in a circle and closely resemble fly specks, hence the name. The fungus does not do a great deal of damage, except to render the fruit unsightly, as it does not get into the tissues of the apple. It is most prevalent in moist weather, especially when the foliage is thick, thus preventing good ventilation. Spraying with bordeaux mixture will control the disease. When spraying for this disease alone, a couple of applications should be made in August at intervals of about two weeks.

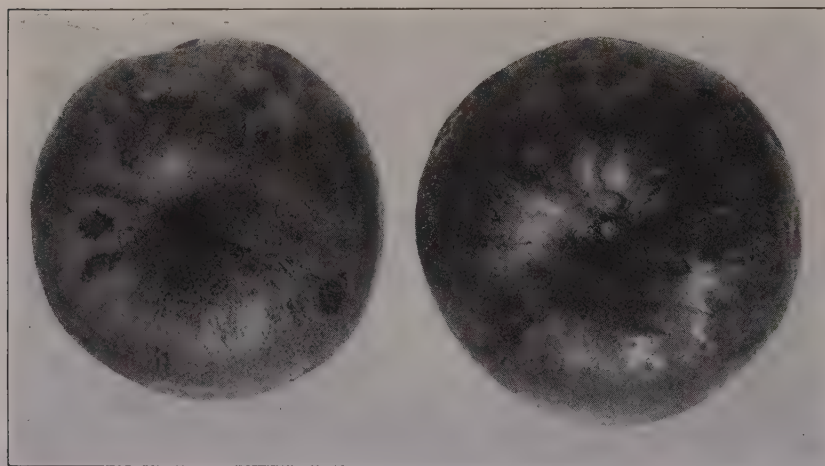


Fig. 16. Sooty Blotch and Fly Speck

Crown Gall (*Bacterium tumefaciens*)

Crown gall is very common on apple trees. Large, irregular galls are produced. These require no more extended description, since they are probably well known to most fruit growers. There is some diversity of opinion as to the damage done by crown gall on apple trees, but there is no question of its destructiveness on raspberries and blackberries. The same germ causes both and is transferable from one host to the other. This should be remembered in dealing with the disease. The only method of prevention is to set out healthy trees on uninfected soil.



Fig. 17. Crown Gall on Apple

Cankers³

Several cankers occur on apple trees in Minnesota. Besides fire blight cankers, bitter rot cankers, and black rot cankers, there are others caused by different fungi which are destructive in certain localities.

³ For further information see Stakman, E. C., and Newhall, A. G. Fruit tree cankers and their control." State Entomologist's Circ. 51. 1918.

In general, in controlling these cankers, all wounds and bruises on the trees should be protected. When the cankers appear they should be pruned out. If valuable limbs or the trunks are affected, it sometimes is sufficient to scrape out all the diseased area thoroly. The wounds may then be disinfected and covered with coal tar or liquid asphaltum. Wounds from an inch to an inch and a half in diameter do not usually require treatment. After this pruning the very thoro use of a lime-sulfur wash will sometimes keep the trees in good condition. This should always be followed by spraying in order to control all diseases of leaves and fruit, as some of them may also appear on the woody parts of the tree as cankers. These precautions, together with care in selecting nursery stock when trees are replaced, should keep the cankers fairly well in check. Whenever tree surgery is necessary, the work should be done by an experienced person.

Scald⁴

Scald is a transportation and storage disease that is produced by the gases given off by the apples themselves. It is particularly common on the York Imperial, Grimes, Rome Beauty, Rhode Island Greening, Stayman Winesap, Wagener, and Baldwin varieties, none of which are commonly grown in Minnesota, and at times may occur on almost every variety of apples.

Scald in general is found on the greener side of the fruit, and in mild cases appears as mere tinted brown areas, but in more severe cases the skin layer is killed and will slough off readily from the flesh. This rot as a rule does not extend very deep into the flesh of the apple, but is spread over large irregular surface areas. The damage may be caused either before the fruit is put in storage or while in storage, but generally does not manifest itself until the fruit is taken out of storage and exposed to warm air for a few days.

Control of this disease depends upon the picking of mature fruit, wrapping in light weight oiled paper, packing in well ventilated boxes, crates, or barrels and placing in well ventilated storage as soon as packed. Keep the storage temperature below 40 degrees, F.

Internal Break-down

Internal break-down is a nonparasitic disease and is particularly common on over-ripe fruit. It may appear at picking time, but more commonly it does not appear until the apples are in storage. It occurs on all varieties, but especially upon the summer and early fall apples. It is characterized by a breaking down and browning of the interior of the apple. The riper side of the apple and the blossom end in

⁴ Brooks, Chas., Cooley, J. S., and Fisher, D. F. "Diseases of apples in storage," U. S. Dept. of Agr. Farmers' Bul. 1160. 1920.

general are most affected. The spots may be quite moist at first, but later become spongy and rather dry and mealy. The skin usually retains its normal color, but sometimes becomes darker and in later stages of the disease frequently cracks. To control the disease, provide good ventilation.

Frost Injury in Storage

This type of injury to apples is very similar to break-down. The internal browning that results from freezing often extends to the surface and is usually quite watery. The conducting vessels can often be seen extending through the flesh of the apple as dark brown strands. The skin usually becomes darker in color and frequently becomes a very dark brown if bruised. Frost injury may show at any place on the fruit regardless of the degree of ripeness. Control measures are obvious.



Fig. 18. Jonathan Spot Rot

Note sunken areas. It occurs mostly on over-ripe fruit.

Jonathan Spot Rot

Jonathan spot is a nonparasitic disease and is apparently associated with a varietal weakness in the epidermal tissue of the apple. It is particularly common on Wealthy apples in Minnesota, but also occurs on other thin-skinned varieties. The disease varies with the season, but is found in all sections where susceptible varieties are grown.

This disease appears upon the apple as small brown spots. These spots are very shallow while in the early stage of development, but later they become somewhat enlarged and a corky layer develops immediately

beneath. Jonathan spots differ from those of either fruit spot or bitter pit in being more superficial and in having a solid brown color and a clear cut margin.

Jonathan spot may occasionally appear on the fruit before it is picked, but the disease develops chiefly after it has been picked. Fruit held in common storage is very susceptible to the disease, and it may also appear upon the fruits after being removed from cold storage. In general the more highly colored apples are more likely to be affected than the greener ones, but in storage the greener seem to be more susceptible to the disease. Large apples are more susceptible than smaller ones. To control the disease, put the fruit in cold storage as soon as picked and upon removal from cold storage, keep in a cool place.

Storage Rots⁵

Storage rots are caused by several different fungi, which usually require fairly high temperature and rather moist air in order to work most effectively. It follows, therefore, that the rot can be lessened somewhat by storing only sound apples under good storage conditions.

ASPARAGUS

Rust (*Puccinia asparagi*)

The rust of asparagus is sometimes destructive in Minnesota. The tall branching plants, which spring up after the cutting season, are affected. Numerous oblong, orange-red spots are formed on the stems and leaf-like branches. Rust takes the nourishment from the plant and prevents the storage of the food in the underground rootstocks which is necessary for production of a good crop of succulent stems the following spring. Later in the season the black resting spores develop, replacing the orange-red spots with black or brownish-black patches.

The black spores live over winter and the destruction of all diseased plants, therefore, should lessen the amount of rust the following year. Asparagus often escapes from cultivation and grows along the fence rows. When such plants are affected, unless destroyed, they serve as a source of early spring infection. If the disease is very destructive, spraying with resin-bordeaux mixture may be financially profitable. Spraying should be begun after the cutting season when the new shoots are about eight inches high. Subsequent applications should be made every ten days or two weeks until about the middle of September.

⁵ Brooks, Chas., Cooley, J. S., and Fisher, D. F. "Diseases of apples in storage," U. S. Dept. of Agr. Farmers' Bul. 1160. 1920.

Progress has been made by the United States Department of Agriculture in developing rust-resistant strains.⁶ Seed and stocks of rust-resistant varieties have been secured by the Minnesota Agricultural Experiment Station and are being increased for distribution.

BEAN

Anthracnose (*Colletotrichum lindemuthianum*)

Anthracnose attacks the leaves, stem, and pods. It is probably most conspicuous on the pods, where it forms dark, sunken spots. On the leaves it may become serious enough to involve large areas and very materially decrease the surface, rendering the production of a normal crop impossible.

The disease is carried over winter in the seed. If it is to be controlled, therefore, one of the greatest essentials is the selection of absolutely clean seed. If possible, seed should be obtained from a field which is known to have been free from disease. If this is not possible, pod selection may be practiced, if conditions make it practical. Only those pods which are absolutely clean should be used. Beans to be used for seed should not be threshed on a floor on which diseased pods have been threshed, and should not come in contact with anything which has contained diseased seed, until the container has been very thoroly disinfected. If the disease appears, the vines should not be cultivated when they are wet, as this may spread the disease to other plants.

The strictest sanitary precautions should be observed in addition to the specific methods mentioned. A cultivator that has been used on a diseased field should not be used on a clean field unless it is thoroly disinfected by washing with a strong solution of either formaldehyde or corrosive sublimate. Refuse from a diseased crop should not be allowed to accumulate in or near a field which is to be used for beans. Spraying may, under certain conditions, be of some value, but experiments covering several years have not proved financially successful in Minnesota.

Blight (*Bacterium phaseoli*)

All the above-ground parts of the bean plant are susceptible to blight. The disease is very noticeable on the leaves, where it may form large water-soaked areas which later become thin and papery. All the leaves may sometimes be very seriously affected. On the pods fairly large spots, resembling somewhat those of anthracnose, are formed. However, the spots are shallower, more reddish in color, and have more irregular outlines than those caused by anthracnose.

Blight, like anthracnose, is carried over winter in the seed. Seed should therefore be obtained from fields known to have been free from the disease. Pod selection is not always successful, as some of the seeds

⁶ Norton, J. B. "Washington asparagus; information and suggestions for growers of new pedigreed rust-resistant strains." U. S. Dept. of Agr. Bur. Pl. Indus. C. I. and F. C. D. Circ. 7. 1919.

may be infected and no very distinct indications appear on the surface. When diseased seed is planted, the disease may spread very rapidly by means of insects and dust, and by means of cultivation when the vines are wet.⁷



Fig. 19. Mosaic Disease of Bean

Note the lighter color and smaller size of the plant in the central foreground, also the crinkling of the leaves.

Mosaic

Mosaic is common in Minnesota and is often very destructive. Affected plants are stunted and yield much less than healthy ones. Leaves of affected plants are crinkled and curled and are mottled with light and dark green patches.

Mosaic is caused by a filterable virus and is highly infectious. The disease may be spread by insects or cultivating machinery. It is commonly carried over in the seed.

The use of seed from mosaic-free fields or seed selection from healthy plants is the best method of control. Spraying or seed treatment is not effective.

Downy Mildew (*Phytophthora phaseoli*)

Downy mildew is not often serious in Minnesota. It attacks the pods and leaves and sometimes the stems. It produces white moldy patches which may be sufficiently severe on the pods to destroy them, and may also get into the seeds. For this reason clean seed should be selected, and clean culture, including the burning of old vines in the fall, and crop rotation should be practiced. Thoro spraying with bordeaux mixture will control the disease to a certain extent.

⁷ Rapp, C. W. "Bacterial blight of beans." Okla. Agr. Exp. Sta. Bul. 131. 1920.

Rust (*Uromyces appendiculatus*)

This refers to the true rust, not the bacterial spot often called rust.

Small brownish pustules which later become black are produced, usually on the under surface of the leaves. On the upper surface the spots may appear pale and yellow. The disease is not very prevalent in Minnesota. Clean culture methods will probably aid considerably in keeping the disease in check.

BEET

Leaf Spot (*Cercospora beticola*)

Grayish to brownish spots with purplish borders are quite frequently found on leaves affected with leaf spot. Usually they are not sufficiently numerous to cause much damage. However, on both garden and sugar beets they may sometimes be serious enough to cause a great decrease in vigor. On garden beets spraying with bordeaux mixture if begun early enough, gives good results. If the beets are grown on a fairly large scale, clean culture methods and strict sanitary precautions should be observed.

CABBAGE*

Black Rot (*Bacterium campestre*)

Black rot is rather destructive in Minnesota. It is a bacterial disease which usually first makes its appearance along the edges of the outer leaves, as grayish black irregular spots. Affected leaves turn yellow, wilt and often fall off. The veins are blackened, and if they are cut a sticky yellowish mass of bacteria may ooze out. The decay may spread rapidly from the leaves down to the main stem and from there to all parts of the plant. In the later stages other organisms often follow the black rot bacteria, aiding in the destruction and reducing the plant to a slimy foul smelling mass which dries up, leaving only a bare stump. This condition is commonly known among cabbage growers as "stump rot."

The losses from black rot are not confined to the field. Heads harvested from diseased fields may decay in storage. For this reason all heads that show any indication of rot should be rejected.

Control measures consist in planting disease-free seed; preparing a very good seedbed; careful rotation of crops; control of insects; pulling and burning of affected parts; and clean culture methods, including the keeping of stock out of a diseased field, especially if it is afterwards allowed to run in fields which may be used for cabbage in the future. The seed should be soaked for fifteen minutes in formaldehyde used at

* For the best discussion of cabbage diseases see Harter, L. L., and Jones, L. R. "Cabbage diseases." U. S. Dept. of Agr. Farmers' Bul. 925. 1918.

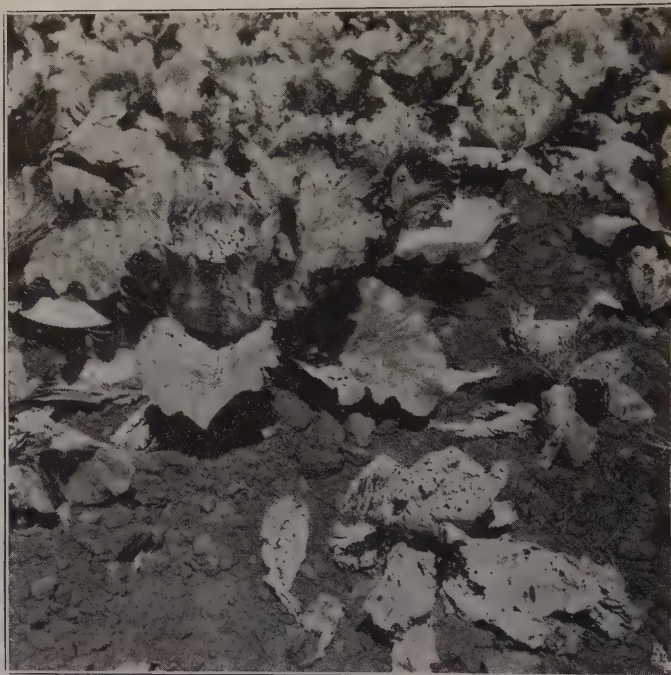


Fig. 20. A. Cabbage Plants Affected with Club Root, in Field.

the rate of $\frac{1}{4}$ pint to 7 gallons of water, or 30 minutes in mercury bichloride (1-1000), and then washed with water and dried. In planning the rotation, remember that the disease attacks not only cabbage, but also closely related plants of the mustard family, both wild and cultivated, including cauliflower, turnip, kale, rape, kohlrabi, brussels sprouts, collards, rutabaga, radish, and wild mustard. None of these vegetables, therefore, should be used in a rotation, and wild mustard should be kept out of the cabbage patch. The control of insects is necessary, as they very frequently spread the disease. Manure from stock which has been fed diseased cabbage should never be put on cabbage soil.

Club Root (*Plasmodiophora brassicae*)

Club root is caused by a slime mold and produces large tumor-like growths or galls on the roots of practically the same kinds of plants that are attacked by black rot. Affected plants are usually below normal in vigor, in many cases failing to head. The same general sanitary precautions mentioned under black rot should be practiced in attempting to control club root. A rotation should always be practiced. The severity

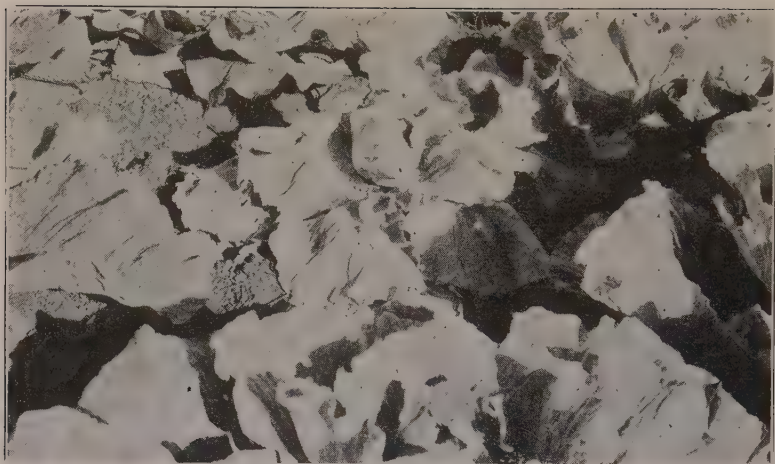
of the disease can be reduced by working into the soil 150 bushels of air-slaked lime per acre just before planting time, and by providing good drainage.



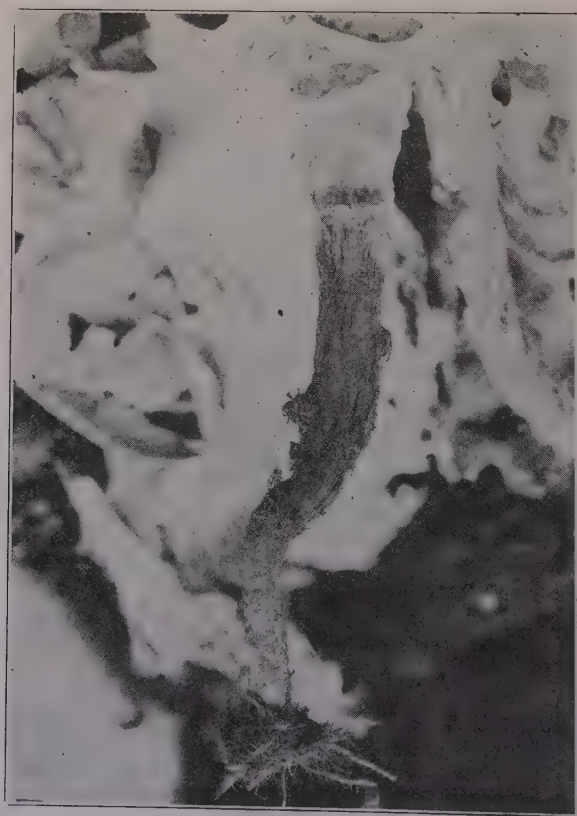
Fig. 20. B. Same Plants as in "A" Pulled Up.

Soft Rot (*Bacillus carotovorus*)

Soft rot is likely to follow black rot, the bacteria causing it usually gaining entrance through wounds. Plants may be affected in the field or in storage and serious losses often occur during shipment. When storage conditions are favorable to the spread, a large amount of cabbage may be destroyed in a comparatively short time. The affected portions usually become soft and slimy. When the rot gets into the



A. Wilted plant affected with blackleg.



B. Root and stem of the same plant.

Fig. 21. Blackleg of Cabbage

fleshy portions it may cause them to become almost amber colored and nearly transparent. When these parts are handled, they often fall apart into a slimy, foul-smelling mass.

The disease can be controlled very largely by means of proper rotation and the maintenance of proper storage conditions. When plants are harvested from a diseased field, they should be dried in the sunshine before storing. The storage house should be cold and well ventilated. Soft rot may occur on several vegetables, including turnips, rutabagas, and other root crops; for this reason, susceptible plants should not be grown in the rotation. (See "Soft Rot of Vegetables.")

Blackleg (*Phoma lingam*)

Cabbage and cauliflower are susceptible to blackleg. The plants usually are attacked when they are young, but they may also become affected when older. Sunken spots appear on the leaves and stems. When stems are affected the lesions usually progress toward the roots. The plants often become purplish and may wilt and die. Large numbers of very small black eruptions may be found scattered over affected parts.

Control measures consist in rotation and clean culture methods. The Ohio station recommends treating the seedbeds with 4-4-50 bordeaux mixture at the rate of one gallon to ten square feet of soil, just before sowing the seed.⁹ The Bureau of Plant Industry, United States Department of Agriculture, has also shown that steam sterilization of the soil in a seedbed for one hour at a temperature of 212 degrees F., is effective.¹⁰ Two additional applications of bordeaux mixture are made, one two weeks before the plants are set out in the field and another just before transplanting. All diseased plant parts should be disposed of, and stock should be kept away from diseased patches. Crop rotation should be practiced and the seed should be disinfected as for black rot.

Yellows; Wilt; Yellow Sides (*Fusarium conglutinans*)

Yellows usually appears from two to four weeks after the plants are set out. However, it may also occur in the seedbed. The outer and lower leaves first become yellow, quite often between the veins and near the margins. Later they dry and drop from the plant. Sometimes this occurs on one side of the plant only, while the other side remains fairly healthy. The disease practically always causes the lowest leaves to drop off first and progresses until nothing but the bare stalk may be left, heads being very rarely formed. The stem may become brown, especially in the woody portions, the dark color often forming a more or less incomplete ring.

⁹ Manns, Thos. F. "Two recent important cabbage diseases of Ohio." Ohio Agr. Exp. Sta. Bul. 228. 1911.

¹⁰ Harter, L. L., and Jones, L. R. "Cabbage diseases." U. S. Dept. of Agr. Farmers' Bul. 925. 1918.

Control measures consist in obtaining clean seed and planting it in a clean seedbed, and in clean culture methods. The seed should be disinfected as for black rot. The seedbed should be very thoroly prepared and sterilized whenever possible. Any plant which becomes diseased in the seedbed or shows any signs whatever of disease should be destroyed. Stock should not be allowed to feed on diseased plants and then go to other fields which may again be used for cabbage. Clean cultural methods, including the destruction of diseased plant parts, should always be practiced. Manure from stock which has been fed diseased plants should not be put on cabbage land. Resistant strains of cabbage have been produced at the University of Wisconsin.¹¹

Downy Mildew (*Peronospora parasitica*)

Downy mildew usually appears in the seedbeds, very seldom in the fields. It produces grayish white patches on the under surface of the leaves, and yellowish or light brown areas on the upper surface. The disease is not important.

Control measures consist in clean culture, rotation, and care in the seedbed, especially in planting and watering. The plants should never be crowded too much and should not be kept too wet. As soon as the disease appears, all the affected parts should be removed and destroyed. Spraying with 4-4-50 bordeaux mixture when the plants are very young will keep the disease in check. When they are set out in the field all that show any signs of the disease should be rejected.

CELERY

Early Blight; Leaf Spot (*Cercospora apii*)

Yellowish, angular spots with somewhat raised borders appear on both sides of the outer leaves and later on the inner leaves of plants affected with early blight. As the disease progresses the centers of the spots become ashy gray in color, the leaves wilt and dry and may fall from the plant. The disease may progress in storage if diseased plants are stored. Muggy weather is very favorable to the spread of the disease and this should be taken into consideration in attempting to control it.

Control measures consist in spraying and clean culture methods. The spraying should be begun in the seedbed if the disease has previously been severe or has been in the neighborhood. It should be continued at intervals of ten days or two weeks, depending upon weather conditions and the severity of the disease. Either 5-5-50 bordeaux

¹¹ Jones, L. R., and Gilman, J. C. "The control of cabbage yellows through disease resistance." Wis. Agr. Exp. Sta. Res. Bul. 38. 1915.

Jones, L. R., Walker, J. C., and Tisdale, W. B. "Fusarium resistant cabbage." Wis. Agr. Exp. Sta. Res. Bul. 48. 1920.

mixture or ammoniacal copper carbonate may be used. It is important to use high pressure and apply the spray material in the form of a fine mist in order to avoid staining the celery too much. Severely affected plants should not be stored. As an added precaution, if the disease has been severe, the plants that are stored should be dipped into bordeaux mixture before being stored.

Late Blight (*Septoria petroselini* var. *apii*)

Leaf spots, at first somewhat like those of early blight, appear on leaves affected with late blight. A characteristic feature is that as the affected part becomes older, numerous small, black eruptions appear. The disease also attacks the petioles, and in extreme cases may cover almost the entire plant, rendering it unsightly and lessening its salability very materially. The leaves may rot entirely, either in the field or in storage. The disease may spread on stored plants; especially if the storage cellar is warm and moist.

Control measures are practically the same as for early blight. It is especially important that spraying be begun as soon as the plants come up, as the disease often appears on the young plants and is difficult to control after it once gets started.¹²

Yellows (*Fusarium* sp.)¹³

Celery yellows is a stunting disease of celery. Diseased plants are much smaller than healthy ones, and the foliage has a decided yellow appearance. The leaves are much thickened and are usually somewhat curled. If the stem or the leaf is split open, the veins may be found to have a reddish color. This disease has been studied in Michigan and control measures have been worked out there.¹³

The fungus causing the disease lives in the soil from year to year, making it hard to control. The Golden Self-Blanching variety is especially susceptible to the disease. Easy Blanching and all the so-called green varieties are somewhat resistant. If this disease is found in a celery field the Easy Blanching or one of the green varieties should be substituted for the Self Blanching. Long-time crop rotation might be helpful, but the best way to avoid losses from the disease is to grow the more resistant sorts.

¹² Coons, G. H., and Levin, Ezra, "The *Septoria* leaf-spot disease of celery or celery blight," Mich. Agr. Exp. Sta. Spec. Bul. 77. 1916.

¹³ Coons, G. H., and Nelson, Roy. "Celery yellows," *Phytopath.*, 11:54-55. 1921. (Abst.)

CHERRY

Brown Rot (See Plum.)**Shot Hole** (See Plum.)

CUCUMBER

Wilt (*Bacillus tracheiphilus*)

Wilt is caused by a bacterium which may attack other cucurbits as well as cucumbers. The signs of the disease are rather striking. The leaves or any part of the vine may droop and wilt in a very short time. The appearance is simply that of plants wilting from lack of moisture. If a wilted vine is cut, a white, sticky ooze usually comes out from the sap tubes. The disease is spread very largely by biting insects, especially the striped and twelve-spotted cucumber beetles, which should, therefore, be controlled. All diseased vines should be immediately destroyed.

Mosaic; White Pickle

Mosaic has been known in Minnesota for several years as "nubbin," "wart disease," and "white pickle." It appears both in the field and under glass. The leaves of affected plants, especially the younger ones, develop a yellow and dark green mottling accompanied by a crinkled or savoyed appearance. The older leaves turn yellow and may fall off leaving a rosette-like cluster of young leaves at the end of the bare vine. The fruits are also mottled with green and yellow and often develop dark green wart-like patches, or the entire fruit may be yellowish white.

No visible organism has been associated with the disease, but the juice of affected plants is known to contain some infective principle by means of which the malady can be spread from plant to plant. This infectious virus shows many of the properties of living organisms and may probably be a parasite too small to be seen even under a microscope.¹⁴

Mosaic is spread from plant to plant by means of insects or by human agencies during the processes of cultivation. Perhaps the most common means of spread in a greenhouse is the pruning knife. The wild cucumber and several other weeds are also susceptible to the disease.¹⁵ Such plants undoubtedly serve as sources of primary infection for the cucumber. Transmission through the seed probably occurs in rare cases.

The following methods of control are recommended: (1) Destroy diseased plants as soon as they appear. (2) Control cucumber insects, especially plant lice. (3) Cage plants to keep insects away. (4) Practice clean cultivation to destroy any weeds likely to harbor the disease.

¹⁴ Doolittle, S. P. "The mosaic disease of cucurbits." U. S. Dept. of Agr. Bul. 879. 1920.

¹⁵ Doolittle, S. P. "The relation of wild host plants to the over-wintering of cucurbit mosaic." Phytopath, 11:47, 1921. (Abst.)



Fig. 22. Cucumber Wilt in a Greenhouse



Fig. 23. Cucumber Mosaic on Leaves

The fruit from such plants is usually small, knotty, and deformed.

In greenhouses where pruning is practiced, the pruning knife should be disinfected with corrosive sublimate (1-1000) after pruning each plant and before passing to another. A very convenient way to do this is to fasten a can of the solution to the belt and to use two knives, keeping one in the solution while the other is in use, exchanging after pruning each separate plant.

No variety of cucumber is known to be resistant.

Downy Mildew (*Plasmopara cubensis*)

Downy mildew is usually not serious in Minnesota. Yellow spots appear first on the old leaves and later on the younger ones. The disease may spread rapidly in warm, moist weather. Affected portions may dry and fall. In extreme cases few fruits are produced, and those which mature are usually small and deformed. The disease can be controlled by spraying with 5-5-50 bordeaux mixture. This should be begun as soon as the vines begin to run and should be continued at intervals of ten days or two weeks, the time depending on the prevalence of the disease.

Powdery Mildew (*Erysiphe cichoreacearum*)

Powdery mildew produces characteristic powdery patches. It is ordinarily not destructive and the control measures suggested for downy mildew should keep it in check.

Scab (*Cladosporium cucumerinum*)

Scab occurs on both leaves and fruits. On the leaves, watery, semi-transparent spots are first produced. A wilt soon follows and in a short time the entire leaf may rot. An infected plant may be entirely destroyed in a few days.

The fruits are attacked shortly after being formed. The spots appear as velvety, gray, sunken patches about an eighth of an inch in diameter. They soon unite, causing large irregular areas which later become greenish black, especially near the flowering end. A gummy liquid is often exuded.

This disease can be fairly well controlled by thoro spraying with 3-6-50 bordeaux mixture when the vines begin to run, followed at ten-day intervals throughout the growing season by applications of 4-4-50 bordeaux mixture. Clean culture is also essential.



Fig. 24. Nectria Canker on Currant

Millions of spores which spread the disease are produced in the light pink disks scattered about the canes.

Anthracnose (See Melon.)

CURRENT

Leaf Spot (*Pseudopeziza ribis* and *Septoria ribis*)

Several leaf spots of currant occur in Minnesota. They can all be discussed together since control methods are approximately the same. Altho not always serious, they may sometimes cause the leaves to fall prematurely and consequently decrease the amount of fruit produced.

Spray with bordeaux mixture as soon as the leaves unfold and repeat as often as is necessary to protect the leaves. Rake up diseased leaves and burn them or plow them under in the fall or early in the spring.

Powdery Mildew (*Sphaerotheca mors-uvæ*)

The fungus causing powdery mildew produces grayish patches which later become brown and felt-like. The leaves and fruit are most often affected. Potassium sulfide, used at the rate of 1 ounce to 2 gallons of water, is fairly effective. Bordeaux mixture as applied for leaf spot will also aid somewhat in keeping the disease in check.

Rust (*Puccinia grossulariae*)

Currant rust is usually not injurious, but is found quite frequently. It occurs as orange-colored swollen or thickened spots on the leaves and sometimes on the fruits. These spots are composed of small cups imbedded in the host tissue which contain the spores of the fungus. Spraying as for leaf spot will probably reduce the rust to a minimum.

This rust should not be confused with black stem rust of wheat which grows on the common barberry bush. The currant rust will not affect wheat or other small grains nor will the black stem rust grow on currants.

Cane Blight (*Nectria cinnabarina*)

Cane blight usually follows other injury. Affected canes may be covered almost entirely with small, pinkish or salmon-colored disks. The only control methods that can be suggested are to avoid injury to the cane and to cut out and burn affected canes when they appear.

GINSENG

Blight (*Alternaria panax*)

Ginseng blight occurs on both leaves and stems. Large watery spots, which later become dry, are produced on the leaves, and brownish canker-like areas are produced on the stems. Infection often takes place just as the shoots appear above ground.

Control measures consist in spraying and sanitation. The first spraying should be given before the plants come up. At this time copper sulfate solution made up at the rate of 1 pound of copper sulfate to 10 gallons of water should be used. As soon as the plants appear above the surface of the ground they should be sprayed with 3-3-50 bordeaux mixture. The spraying should be repeated at frequent intervals, the object being to keep the leaves and stems well covered with the spray material in order to protect them, especially during wet weather. All diseased parts should be destroyed. If possible, the beds should be covered with straw and burned over after the tops have died.

GOOSEBERRY

Powdery Mildew (*Sphaerotheca mors-uvae*)

Leaves, stems, and berries may be affected with powdery mildew. Mildewed areas first look as if they had been dusted with flour, but later they become brownish. Powdery mildew is one of the most serious diseases on gooseberries, but it can be controlled almost entirely by proper spraying. Potassium sulfide, used at the rate of 1 ounce to 2 gallons of water, has proved very effective. The first spraying should be given just as soon as the leaf buds begin to break, and spraying should be repeated at intervals of about ten days or two weeks.

Leaf Spot (*Septoria ribis*)

Leaf spot of gooseberry sometimes becomes quite serious, the chief loss resulting from defoliation. Spraying as for currant leaf spot probably will control the disease.

Rust (*Puccinia grossulariae*)

Rust is sometimes abundant on the leaves, but seldom does much damage. It appears as yellowish or orange-colored cluster cups. Spraying may prevent it to a slight extent.



Fig. 25. Black Rot on Grape



Fig. 26. Downy Mildew on Grape

Note the mildewed appearance of the leaves and branches.

GRAPE¹⁸

Black Rot (*Guignardia bidwellii*)

Black rot appears on the leaves of grape as circular tan-colored or brownish patches in which there are small black bodies arranged in a more or less complete circle. On the berries it first appears as small brownish or purplish spots which may enlarge very rapidly under

¹⁸ For grape diseases, see Hesler and Whetzel, "Manual of fruit diseases," pp. 229-267. 1917.

favorable weather conditions until the entire fruit is rotted. The berries shrink and become very much wrinkled, forming hard, dry mummies. Young shoots may sometimes be affected. On the shoots the spots usually are reddish in color.

The disease over-winters very largely on the mummied berries which have fallen to the ground. In attempting to control the disease, therefore, clean culture methods should be practiced. All mummied fruit that still remains on the vines should be destroyed. The vineyard should be cultivated early in the spring to turn under all mummied berries and affected leaves. All grasses and weeds should be kept down



Fig. 27. Mummied Grapes Caused by Downy Mildew

and the lower sprouts of the vines should not be allowed to spread over the ground. These clean culture methods should be combined with thoro spraying with 4-4-50 bordeaux mixture. The first application should be

made about the time the second or third leaf appears and the second one before the flower buds open. The third application should be made soon after the blossoms have dropped. These may be followed by two or more applications at intervals of two weeks.

Downy Mildew (*Plasmopara viticola*)

In downy mildew grayish, felty masses of fungous threads appear, usually on the lower surface of the leaves. The upper surface appears yellow. If green fruit is attacked, the berries become hard. If the berries are older they become brownish in color, and for this reason the name brown rot is sometimes applied. The berries shrivel, but do not become so hard and dry as in the case of black rot. Control measures are the same as for black rot.

Powdery Mildew (*Uncinula necator*)

More or less circular spots, appearing as tho they had been dusted with flour, may be seen on plants affected with powdery mildew. The disease is not often severe in Minnesota, altho under favorable weather conditions it may do some damage. Lack of ventilation, too much shade, and dampness are especially conducive to its spread. The control measures suggested for black rot will help to keep powdery mildew in check.

LETTUCE

Downy Mildew (*Bremia lactucae*)

Downy mildew occurs mainly under glass. Affected leaves first become paler in color and afterwards wilt. The downy, mildewed appearance can be then noticed. Sanitation, good ventilation, and plenty of sunlight are the best control measures.

Gray Mold (*Botrytis cinerea*)

Gray mold appears almost entirely in the greenhouse. The edges of the leaves first wilt, and later the entire leaf may droop and die. The dead plants are often covered with a dirty, grayish brown fuzz. Control measures consist very largely in proper culture methods. Good ventilation, a fairly constant temperature, and avoidance of too much water, aid very much in keeping the disease in check.

Drop (*Sclerotinia libertiana*)

Drop has been considered chiefly as a greenhouse trouble, but it is very destructive on the peat soils in northern Minnesota. This is especially true where lettuce has been grown for several years in succession on the same soil. Affected plants first begin to wilt around the margins of the leaves, often taking on a reddish tinge and appearing to have been



A. Early stage.



B. Later stage.

Fig. 28. Lettuce Drop

scalded with hot water. Later the outer leaves fall flat on the ground and the entire plant wilts and dries up. If the plant is pulled up when it begins to wilt, a white cottony growth will be found on the under side of and between the leaves. Later the head begins to decay and careful observation will show black irregular shaped leathery masses of fungous growth about the size of a pea scattered about in the decayed tissue. These are masses of fungous tissue known as sclerotia which are very resistant to adverse conditions and serve as a means of carrying the fungus over winter. These sclerotia lie in the soil over winter and in the spring begin to grow again, sending up to the surface of the soil

little mushroom-like structures on the surface of which are great quantities of spores. These spores are scattered by wind and rain to healthy plants on which they grow and start the disease again.

As the fungus depends upon these sclerotia for living over the winter, the most practical means of controlling the disease is to prevent their formation. This can be done by pulling up the diseased plants as soon as they show the first signs of wilting, destroying them, and pouring a cup of copper sulfate solution into the hole left by pulling the plants. The copper sulfate solution is made by dissolving one pound of blue-stone (blue vitriol) in seven gallons of water.

Crop rotation is also a helpful practice, but can not alone be depended upon. The fungus has a wide host range and the sclerotia may remain viable in the soil for several years. Celery, especially, is readily attacked by the fungus and should not be included in a rotation.

MUSKMELON

Anthracnose (*Colletotrichum lagenarium*)

All parts of the vine and the fruit may be affected by anthracnose. The tendrils, buds, and petioles may blacken and die. On the leaves, fairly large, dark blotches may appear. These later dry and sometimes fall out. On the stems, the spots are elongate and light brown in color; on the fruit, deeply sunken, more or less circular spots, sometimes with pinkish centers, are developed. Spray as for downy mildew of cucumber, rotate crops, and destroy diseased material. All seed should be disinfected with corrosive sublimate before planting.

Leaf Blight (*Macrosporium cucumerinum*)

Leaf blight is sometimes rather serious in Minnesota. In some cases it practically destroys fairly large patches of melon vines within a short time. The disease appears as small, brown spots on the leaves. Frequently there are concentric rings in the spots, while a dark, velvety, moldy growth may appear in the center. The spots may enlarge and coalesce, causing the leaves to curl and shrivel. The leaves die and dry up. The leaf petioles are also affected. The disease causes premature ripening and consequently lack of flavor in the fruit. Systematic spraying should be practiced. The general directions given under downy mildew of cucumber may be followed. In addition to the spraying, a rotation should be practiced and clean culture methods should prevail. The Pollock strain of the Rocky Ford cantaloupe is said to be very resistant to the disease.

Downy Mildew (See Cucumber.)

Wilt (See Cucumber.)

ONION

Blight; Downy Mildew (*Peronospora schleideniana*)

The tips of the plants are first attacked by blight and present a water-soaked appearance which is quite often followed by a moldy growth of the affected parts. Later the plants may collapse, thus interfering with the formation of normal bulbs. Crop rotation, clean culture, and spraying will prevent the disease. If it has been serious it may be advisable to spray shortly after the plants appear above ground. The first spraying may be given with 5-5-50 bordeaux mixture and should be followed, when the disease is severe, by one or two subsequent applications of the same material.

PEA

Blight (*Ascochyta pisi* and *Septoria pisi*)

There are two diseases of peas which are very common in Minnesota, and are variously referred to by growers as blight, pod spot, leaf spot, and rust. There are differences between the two, but for practical purposes they may be considered together. The leaves and pods are attacked, and other parts of the vine may also sometimes be affected. On the leaves, grayish spots with darker borders are often prevalent enough to interfere very seriously with the development of the plant. Sometimes small, black eruptions are seen in these spots. On the pods, the same general type of spot is developed. These are usually somewhat sunken and in extreme cases may extend through the pod. The seeds may also become infected. A discoloration quite often indicates this infection, altho in cases of rather light infection there may be no external evidence of the presence of the fungus. Few seeds from diseased pods germinate. As a matter of fact, it has been shown that only 6 per cent of the seeds selected from diseased pods were capable of germination.

Obviously, since the disease is carried over very largely within the seed, one of the first essentials is to get absolutely clean seed. Pod selection should be practiced, and all pods that show any indications whatever of the disease should be rejected. After selection, the peas to be used for seed should not again come in contact with any diseased material or anything which has contained diseased material. Clean culture methods and crop rotation should be practiced. Experiments made at the Wisconsin Agricultural Experiment Station show that when diseased vines undergo fermentative processes in the silo the blight spores are destroyed; and the vines make excellent silage.

Powdery Mildew (*Erysiphe polygoni*)

Powdery mildew may attack the leaves, pods, and vines. It is similar to the powdery mildews in general, forming dirty gray, powdery spots which are sometimes sufficiently large to involve the entire leaf or pod. The disease is carried over by means of seed taken from affected pods. For this reason all the precautions mentioned under blight should be observed in attempting to control mildew. Spraying, if begun early, will also aid in controlling the disease.

PLUM

Black Knot (*Plowrightia morbosa*)

Altho black knot is very common on wild plums, choke cherries, and closely related forms, it seldom does much damage in orchards in Minnesota.

The first sign of the disease is usually the development on young twigs of a velvety, greenish or olive-colored swelling. Later in the season these affected parts become black and brittle. Young twigs are most often affected, but larger branches also may be involved. Sometimes the affected parts are killed, altho this does not necessarily follow. As infection probably takes place very largely through wounds, the trees



Fig. 29. Black Knot of Plum

Note how the infected twigs are bent almost at right angles. The spores which spread the disease are produced in these black swellings.

should be kept in good condition and all wounds and bruises should be protected. The disease spreads very rapidly while the knots are still young, and careful pruning and burning of the diseased parts at that time will aid very considerably in keeping the disease in check, but can not be depended on to control it. Spraying should, therefore, be practiced. A dormant spray would be very valuable, altho this does not seem necessary or profitable in all cases. Spraying as for brown rot will lessen the amount of infection.

Brown Rot (*Sclerotinia cinerea*)

Brown rot attacks the blossoms, leaves, young twigs, and fruit. In some seasons many of the blossoms may be destroyed. Infected flowers become brownish in color and finally dry and fall from the tree. Fairly large brownish spots appear on the leaves and young twigs may be killed rather quickly. The disease, however, is most serious on the fruit. Green plums are sometimes attacked, but the disease spreads most rapidly when the plums are ripening. Affected plums become somewhat brownish in color and finally rot entirely. A grayish or tan-colored powder (spores of the fungus) is produced on the surface of the fruit.

Brown rot is most serious when the weather is warm and moist. Dry weather usually checks it.

The causal fungus over-winters mainly in mummied plums. If possible, therefore, these mummies should be destroyed. This is not practicable in a large orchard unless the orchard can be plowed and most of the mummies turned under.

In order to control brown rot it is necessary also to control the plum curculio, since it is through the punctures made by this insect that most of the brown rot infection occurs. Trees should be sprayed three or four times.¹⁷ The first application should be made just before the flower buds open, the second when the young fruit is about the size of a green pea, and the third when the fruit is beginning to turn. Commercial lime-sulfur plus arsenate of lead has given good results. Weak bordeaux mixture also can be used. It is well to add 2 pounds of resin-fish oil soap to each 50 gallons of spray mixture.

Plum Pocket (*Exoascus pruni*)¹⁸

Plum pocket may occur on the fruit, leaves, and young twigs. It causes the affected parts of the plant to become swollen and distorted.

¹⁷ Stakman, E. C., and Tolaas, A. G. "The control of brown rot of plums and plum pocket." The Minnesota Horticulturist, 46, No. 5 (May, 1918).

¹⁸ Swingle, D. B., and Morris, H. E. "Plum pocket and leaf gall on American plums." Mont. Agr. Exp. Sta. Bul. 123. 1918.

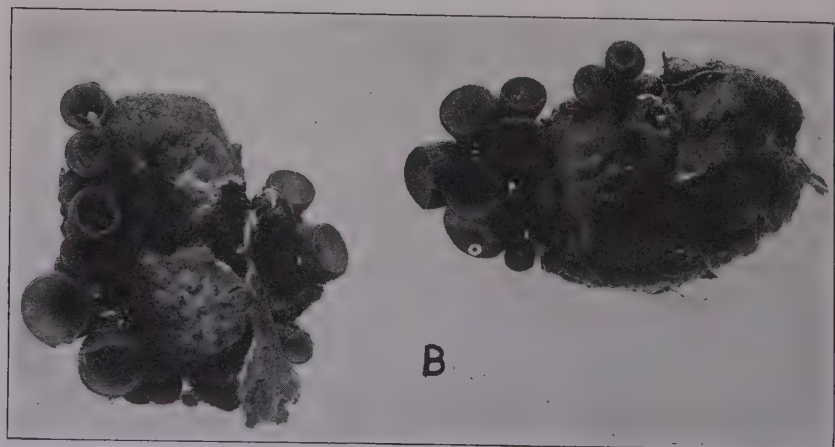
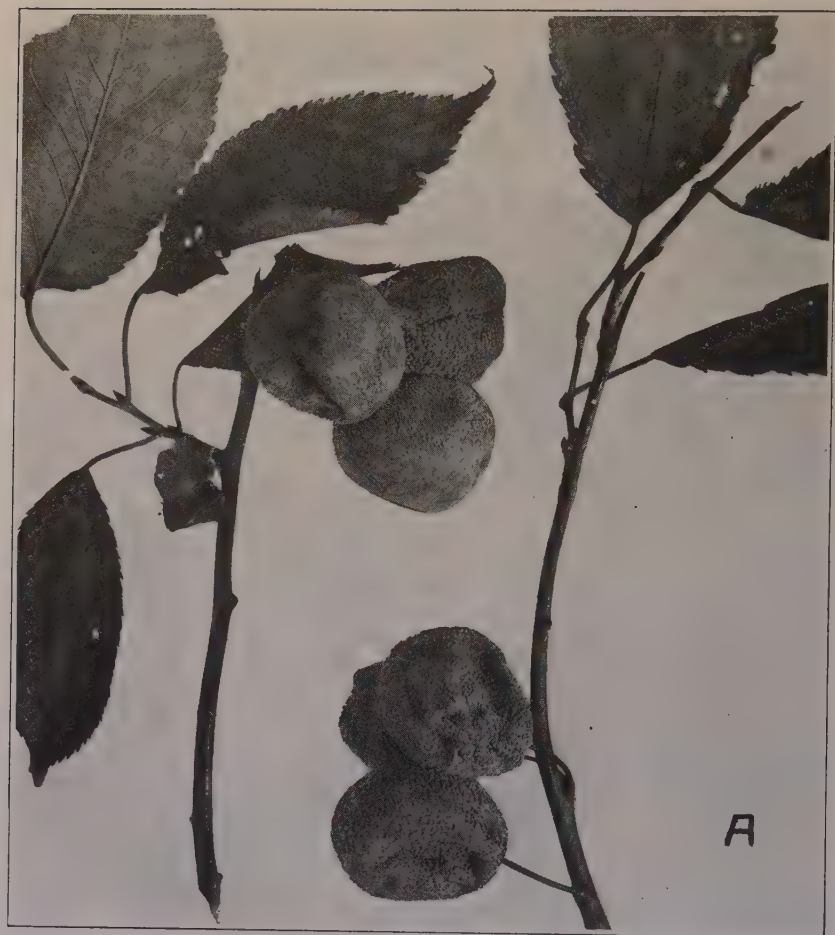


Fig. 30. Brown Rot of Plum

- A. Summer stage, showing small grayish brown tufts of spores on the fruit.
 B. Mummied plums, showing cup-shaped bodies which contain spores.



Fig. 31. Brown Rot of Plum; Twig and Blossom Blight

The pit of the fruit is destroyed and the fleshy portion swells up into a bladder or sack-like structure. (See Fig. 32.) The appearance of the leaves and twigs is somewhat similar.

Plum pocket can be controlled fairly well by proper spraying. The first application should be made when the flower buds are beginning to show color and the subsequent spraying for brown rot will keep the disease well in check. Commercial lime-sulfur, $1\frac{1}{4}$ gallons to 50 gallons of water, has given good results. Bordeaux mixture 4-4-50 may be used in the first spraying, but apparently it is no more effective than lime-sulfur.

Shot Hole (*Cylindrosporium padi* and *Phyllosticta prunicola*)

Very numerous, rather small, brown spots appear on leaves affected by shot hole. Later the diseased areas drop out, giving the leaves the appearance of having been riddled with shot. The damage results mainly from the defoliation of the trees, thus making the production of a normal crop impossible. Shot hole should not be confused with spray injury which sometimes results from drenching the trees with too strong spray mixtures. Spray with lime-sulfur, $1\frac{1}{4}$ gallons to 50 gallons: (1) as soon as the petals fall; (2) about three weeks later; and (3) just after the fruit is picked.

Scab (*Cladosporium carpophilum*)

Scab appears on the fruit in the form of brownish, scabby spots, especially during moist weather. Infection is superficial but renders the plums rather unsightly. Spraying as for brown rot controls the disease fairly well under Minnesota conditions.

(Powdery Mildew (See Apple.)

Fig. 32. Plum Pocket, Bladder Plums, Fool's Plums

Note the puffed, pitless, mis-shapen fruit. Can be partially controlled by pruning and spraying.

Wood Rot

Various wood-rotting fungi attack plum trees and may eventually kill them. When branches are affected, pruning may sometimes prevent the further spread of the rot. The general recommendations given under apple cankers may be followed. Tree surgery, aside from being of somewhat doubtful commercial value, is more difficult than on apple trees on account of the tendency of the plum tree to produce large amounts of gum.

Gummosis

Plum and cherry trees often exude considerable amounts of a gummy substance which is at first very sticky but on drying becomes hard. This does not necessarily indicate the presence of a specific disease; gummosis may follow injury or fungus attack. It may be brought about by several causes. No recommendations for control can be made except to keep the trees in a healthy condition and avoid bruises and over-fertilization.

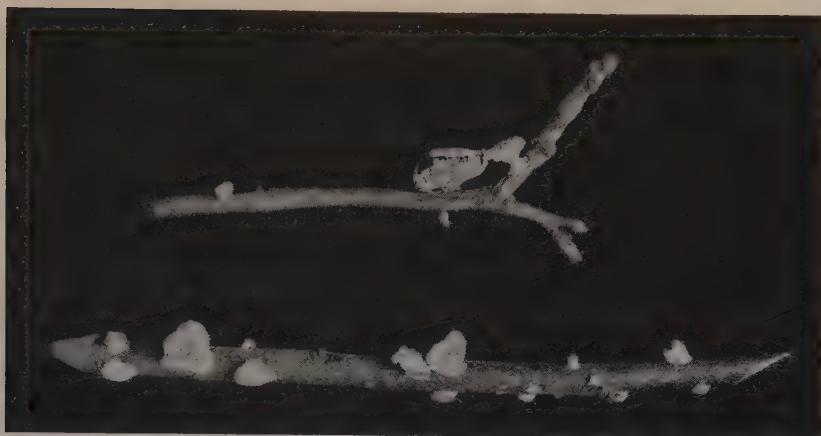


Fig. 33. Wood Rot on Plum Twigs

POTATO

The diseases of potatoes are fully discussed in Minnesota Experiment Station bulletins 181, 190, 192, and 197 which may be obtained on application to the Office of Publications, University Farm, St. Paul. They are therefore not discussed in this bulletin.

RADISH

Club Root (See Cabbage.)

White Rust (*Albugo candida*)

White rust, which is not a true rust, appears on the leaves and flowers as smooth, white blisters. When the flowers are attacked they become very much deformed, interfering with the production of seed. The chief damage occurs in this way. All affected parts should be collected and burned, if the disease is serious enough to warrant any attention.

RASPBERRY AND BLACKBERRY

Anthracnose (*Plectodiscella veneta*)

Anthracnose affects the canes and the leaves. On the canes, ashy gray, sunken areas with purplish borders may be formed in great numbers. On the leaf petioles and on the leaves themselves, grayish spots with purplish borders are very frequently produced. This is one of the very serious diseases in raspberry plantations in Minnesota. After the fruit is picked, all the affected canes should be pruned out and burned. In the spring the very young canes may be sprayed with 4-4-50 resin-bordeaux mixture, altho this is of somewhat doubtful value.

However, an early spraying shortly after the canes begin to grow, followed by one or two subsequent sprayings, sometimes protects them to a certain extent. A rotation should be practiced. Raspberries should never be set out on land which has grown affected canes until several years have elapsed.

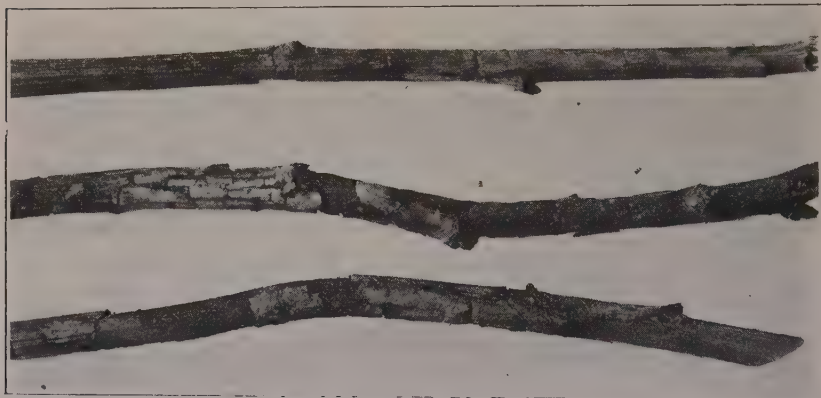


Fig. 34. A. Gray Bark Disease of Raspberry

Note the grayish bark, which is peeling. The wood is dead, and purplish or almost black in color.

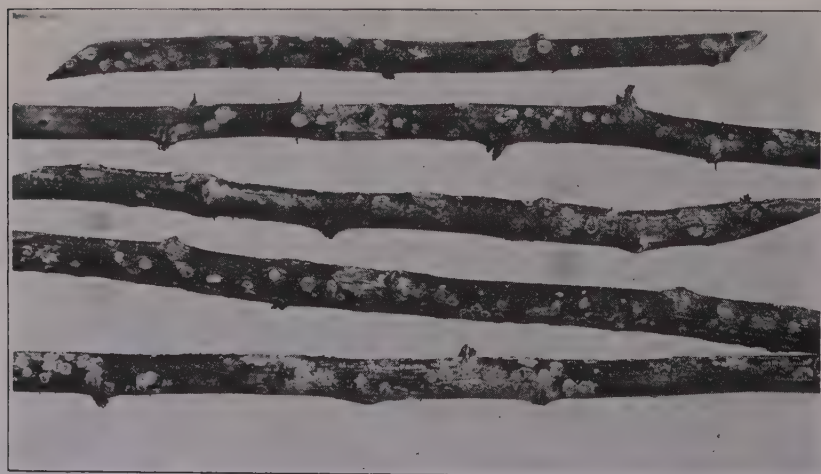


Fig. 34. B. Anthracnose

This is shown by grayish spots with purplish borders. To control both these diseases, cut out and burn all diseased canes. Spray young canes with resin-bordeaux mixture.

Cane Blight (*Leptosphaeria coniothyrium*)

The most striking sign of cane blight is the wilting of the canes. This usually progresses from the tip downward, killing the branches and generally reducing the yield. Diseased canes should be cut out and burned. Care should be taken to avoid bruising the plants. Diseased canes should never be set out. Examine canes carefully before setting them out and make sure that none are affected. The site of the plantation should be changed if the disease has been at all serious. Spraying as for anthracnose may be of some value, but will not control the disease to any great extent.

Gray Bark Disease; Spur Blight (*Mycosphaerella rubina*)

During the last few years the gray bark disease has been extremely common in Minnesota. Bluish or brownish patches are first produced on the canes. Later the outer bark becomes grayish in color and peels off. Small black eruptions usually appear, showing very clearly against the gray background. The wood is usually discolored, assuming a smoky or somewhat purplish tinge. The disease can be distinguished from cane blight by the graying of the bark. The canes do not wilt as they do when affected with the true wilt. Spur blight prevents the normal development of laterals and predisposes canes to winter injury.

Spray with bordeaux mixture 3-2-50, with the addition of resin-fish oil soap at the rate of 2 pounds to 50 gallons of spray. Apply the spray to the young canes when six or eight inches high.¹⁹ Four applications should be made; three at intervals of from two to three weeks before picking and one immediately after picking. Old fruiting canes should be removed and burned immediately after harvest.

Rust (*Gymnoconia inerstialis*)

Rust appears on the leaves as large, bright, orange-colored patches. It also attacks the canes and may often get into the roots. Once a cane is infested it remains so indefinitely. For this reason, spraying is of minor value in controlling the disease. All affected canes should be immediately removed and burned.

Leaf Spot (*Septoria rubi*).

Leaf spot is probably not serious enough under ordinary conditions to warrant spraying, altho it can be controlled fairly well by this means.

The greatest precaution should be taken never to set out any plants which show any signs whatever of this disease; neither should healthy

¹⁹ Sackett, W. G. "Spur blight of the red raspberry caused by *Sphaerella rubina*." Colo. Agr. Exp. Sta. Bul. 206, 1915.

Crown Gall (*Bacterium tumefaciens*)

Crown gall is a bacterial disease which usually attacks the plant on the roots or at the crown. Large, irregular, tumor-like growths are produced. Affected canes are usually sub-normal in vigor and may eventually die. The disease is extremely prevalent and great pains should therefore be taken to control it. It is spread very largely in nursery stock. When the soil is once infested as a result of planting this diseased stock it may remain so for several years. The disease may be spread in the patch by cultivation.

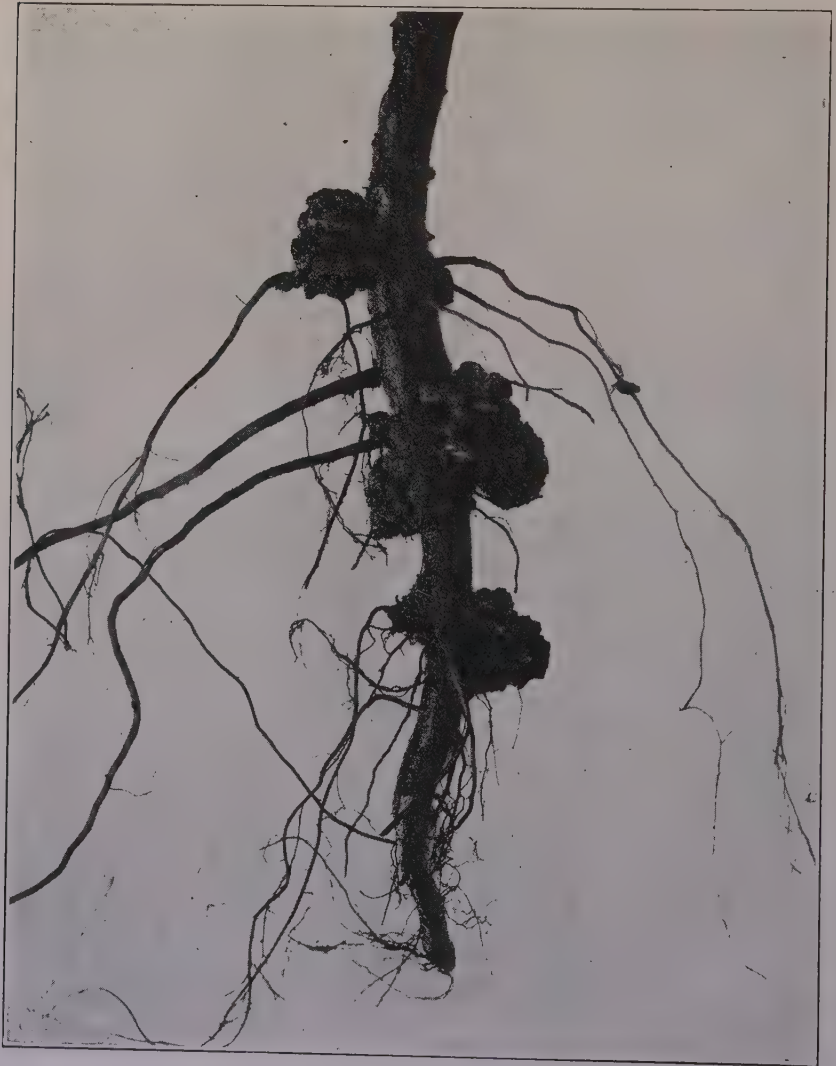


Fig. 35. Raspberry Crown Gall

plants be set out on land which has grown affected bushes. All affected plants should be burned. Not only raspberry, but other small fruits, and large fruits as well, are attacked by the same bacterium. Indications are, however, that there is not so much danger in planting trees of a different kind on affected soil as there is in planting the same kind.

Leaf Curl²⁰

Leaf curl is common on both wild and cultivated raspberries. The leaflets of diseased plants are dark green in color and the mid-rib and main lateral veins apparently are shortened so as to cause a downward curling of the entire leaf. The tissues between the veins often arch upward, giving the leaf a somewhat blistered appearance. The entire plant may be dwarfed and the branches are likely to be shorter than on the healthy plant.

The disease is caused by a filterable virus similar to but not identical with that which causes white pickle of cucumber, tomato mosaic, and other diseases of similar nature.

Plant lice apparently spread the disease by sucking the juice from diseased plants and then transmitting it to healthy ones. In order to control the disease, affected plants should be dug and destroyed as soon as they appear, and plant lice should be controlled by means of spraying.

Yellows²¹

Raspberry yellows is prevalent on both wild and cultivated varieties. It does not seem to be as destructive in Minnesota as leaf curl. The leaves of diseased plants have the calicoed appearance of plants affected with mosaic. In the spring the symptoms of the disease are quite apparent on young leaflets on which there are alternating yellow and green patches causing a mottled appearance. There is a tendency for the production of large green blisters on the new growth. Later in the season the mottling is much finer and the leaves of affected plants appear to be uniformly speckled and yellowish in color. Badly affected plants may be dwarfed considerably; and the entire plant appears yellowish and sickly. Berries are usually small and almost tasteless, normal berries seldom are formed. The disease is worst on Cuthbert and Marlboro.

The disease apparently is spread by plant lice. Control measures are the same as for leaf curl.

SQUASH

Wilt (See Cucumber.)

²⁰ Rankin, W. H., Hockey, J. F., and McCurry, J. B. "Leaf curl and mosaic of the cultivated red raspberry." (Abst.) *Phytopath.* 12:58. 1922.

²¹ Clinton, G. P. "Chlorosis of plants with special reference to calico of tobacco." *Conn. Agr. Exp. Sta. (New Haven) Ann. Rept. Pt. VI.* 1914.

STRAWBERRY

Leaf Blight (*Mycosphaerella fragariae*)

Leaf blight appears on the strawberry leaves about the time the fruit sets. If nothing is done to control it, and conditions are favorable, it may cause considerable injury.

At first the spots are small, round, and reddish or brownish purple in color, increasing in size until they may become one-eighth to one-fourth of an inch in diameter. As the spots increase in size their centers become ashy-gray surrounded by a purple border which shades into the healthy green color of the leaf. In severe cases the spots may become so numerous as to discolor and finally kill the entire leaf.

Such a reduction in leaf surface may result in the production of small berries. The stems may also be involved, causing the berries to dry before they ripen.

The disease can be controlled fairly well by spraying with 4-4-50 bordeaux mixture, once just before the blossoms open and once or twice after the fruit is picked. The leaves may be cut off late in the fall or early in the spring and burned. Care should also be taken when setting out young plants to pick off and destroy all diseased leaves.



Fig. 36. Strawberry Leaf Spot
Grayish spots with reddish borders.

TOMATO

Leaf Spot (*Septoria lycopersici*)

Tomato leaf spot has been serious in Minnesota during the last few years. It appears on the leaves as grayish spots with dark, somewhat raised borders. Sometimes small black eruptions can be seen in the spots. The lower leaves are first affected and the disease progresses upwards. The spots may be so numerous as to involve practically the entire leaf, thus materially decreasing the yield.

The disease can be almost entirely controlled by spraying. As a result of three sprayings with 5-5-50 bordeaux mixture, the first being applied soon after the blossoms fall and the others at intervals of about two weeks, a net profit of from \$70 to \$128 an acre was realized. The spraying must be thoro enough to cover all parts of the vines. The spray material is more effective if 2 pounds of resin-fish oil soap is added to each fifty gallons of bordeaux. Altho the disease was almost entirely controlled by three sprayings each year for the last three years, it may sometimes be necessary to give a fourth spraying, depending very largely upon the severity of the disease. However, during the summer of 1913, when a net gain of \$128 an acre was realized, the disease was extremely serious, and was very largely controlled by three sprayings.

Point Rot; Blossom End Rot

Point rot, as the name indicates, appears on the blossom end when the tomatoes are green. The first indication of the disease is a sunken area at the blossom end, either grayish or brown in color. This diseased area may enlarge quite rapidly until the entire fruit is involved. The affected portions appear to have been dipped in boiling water for a short time.

The cause of the disease has not been fully determined, but it does not seem to be any fungi or bacteria. Plants are more likely to be affected when they are growing rapidly. Either too much water or a sudden cutting off of the water supply may cause the plants to become affected. Plants growing on ground very heavily fertilized with horse manure quite often show more of the disease than those growing on other soil. It seems to be less prevalent on sandy loam than on heavy clay loam. Control measures, as far as can be suggested at present, must depend upon these facts.

Black Rot; Ripe Rot (*Alternaria solani*)

Black Rot is very easily distinguished from point rot, since it may appear on any part of the tomato, and instead of attacking the green fruit, as the point rot does, it attacks the ripe fruit. It causes sunken spots in which a black or olive-colored, velvety mold later appears. It

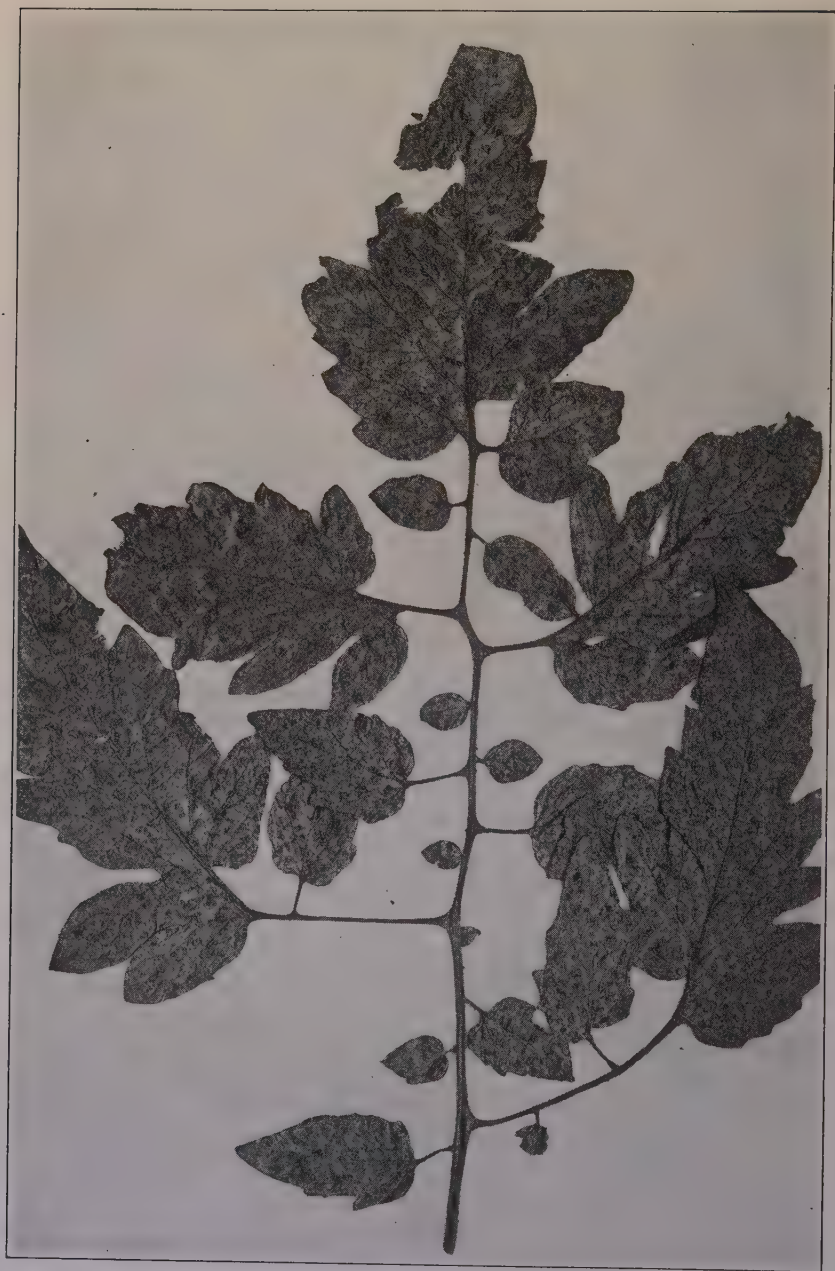


Fig. 37. Tomato Leaf Spot

This can be controlled by spraying with bordeaux mixture.

is most serious when the weather is fairly warm and moist. For this reason, when the vines are trained in such a way as to provide good ventilation, the disease is less severe. This training, together with thoro spraying, will control the disease to a great extent. Spraying as suggested for leaf spot will prevent a certain amount of the disease, but it is sometimes necessary to spray a fourth time in order to prevent late infection.

Leaf Mold (*Cladosporium fulvum*)

Leaf mold is the most important disease of tomatoes in greenhouses. In Minnesota it is seldom, if ever, found on tomatoes in the field.

It appears first on the lower leaves and spreads rapidly upward until the leaves may all fall. Irregular greenish-brown patches occur on the under side of the leaves. On the upper side opposite these patches a yellow discoloration occurs. When the entire leaf is involved it soon dries and drops off. The loss of leaves obviously prevents the proper development of fruit. Good ventilation is essential in controlling the disease. Spraying the vines with 4-4-50 bordeaux mixture when the mold first appears, and keeping the vines covered with the spray material throughout the growing season will aid materially. Clean culture should be practiced.

Mosaic

Mosaic appears on the leaves. Yellowish patches alternate with darker green areas, giving the leaf a peculiar mottled appearance. The affected leaves are often curled somewhat and are sometimes abnormal in shape. Filiform, or thread leaf, is often associated with mosaic; the leaves may become extremely narrow and almost threadlike.

The disease is not due to visible parasites, but is infectious and contagious. It is a common experience for growers to notice that they have spread the disease by means of the pruning knife, especially under glass. The following precautions should be observed: (1) Do not set out affected plants; (2) destroy diseased plants when they first appear; (3) do not touch healthy plants after having touched diseased ones without first washing the hands thoroly with soap and water; (4) disinfect the knife used for trimming the vines with corrosive sublimate, 1 to 1000, after pruning each plant and before pruning another one.²¹

Anthracnose (*Colletotrichum phomoides*)

Anthracnose is characterized by the presence of dark sunken spots on ripe fruit. These may become so numerous as to destroy the entire tomato. Control measures for black rot should aid in keeping the disease in check.



Fig. 38. Tomato Mosaic Disease
A diseased plant is shown at right, healthy plant at left.

TURNIP

Black Rot (See Cabbage.)**Soft Rot** (See Cabbage.)**Club Root** (See Cabbage.)

WATERMELON

Anthracnose (See Muskmelon.)**Downy Mildew** (See Cucumber.)**Wilt** (See Cucumber.)**Vegetable Rots**

Soft rots of vegetables are sometimes very destructive. One species of bacterium is quite often responsible for a great deal of this rot on the various vegetables. Indications are that carrots, rutabagas, onions, parsnips, cabbage, and cauliflower are all affected by the same organism. The rot is especially serious in the field when the weather is fairly warm and wet. The germ may live in the soil for several years and it is therefore advisable to practice a rotation in which a non-susceptible crop is grown on the land. The greatest care should be taken in handling the vegetables, if the disease has been present, as the germ gains entrance almost entirely through wounds. As the germ is killed rather quickly by drying and exposure to sunlight, it is sometimes very beneficial to dry the vegetables as much as possible before storing them. The amount of damage in storage depends very largely on the conditions. High temperature with a considerable amount of moisture is most favorable to the spread of the rot. The temperature of the storage cellar should be maintained just a little above freezing and good ventilation should be provided.

SPRAYING

| PLANT | PEST | SPRAY | FIRST SPRAYING |
|--------------------------------|--|---|--|
| Apple | Codling moth Curculio Scab Black rot Bitter rot Aphids or plant lice Scale insects | Arsenate of lead (1½-50) plus concentrated lime-sulfur diluted (1 to 40), or bordeaux mixture (4-4-50) Bordeaux mixture (4-4-50) Tobacco extract, like Black Leaf No. 40 Lime-sulfur (1-9) | As center bud in flower cluster begins to show pink. When insects appear Before buds burst |
| | Rust | Resin-bordeaux mixture | After cutting season; when about eight inches high |
| Cabbage Cauliflower | Cabbage worm | Arsenate of lead (1½-50 or Paris green (1-50) Dust with the powdered form or with wood ashes | When worms appear |
| Celery | Early blight Late blight | Bordeaux mixture 5-5-50 or Ammoniacal copper carbonate (3-50) | In seed bed |
| | Downy mildew Cucumber beetle Larvae or grubs | Bordeaux mixture (5-5-50) Arsenate of lead or air-slaked lime or ashes Tobacco extract on roots | When vines begin to run Dust as soon as insects appear |
| Currant | Currant worm Leaf spot | Arsenate of lead or hellebore Bordeaux mixture | When insects appear Just as leaf buds break |
| Ginseng | Blight | Bordeaux mixture (3-3-50) | When plants come up |
| Gooseberry | Currant worm Mildew | Arsenate of lead or hellebore Potassium sulfide (Liver of sulfur) | When insects appear Just as leaf buds are breaking |
| Grape | Black rot Downy mildew | Bordeaux mixture (4-4-50) | Before blossoms come out |
| Muskmelon | Anthraxose Leaf blight | Bordeaux mixture (5-5-50) | When vines begin to run |
| Plum and Cherry | Brown rot Curculio Plum pocket Shot hole Scales | Arsenate of lead 1½-50 plus concentrated lime-sulfur diluted 1 to 40), or bordeaux mixture (3-4-50) Copper sulfate Bordeaux mixture Same as for apple | Just before flower buds break Copper sulfate before any growth starts in spring |
| | Blight—early and late Beetle Leaf hopper | Bordeaux mixture (5-5-50) Paris green (1-50), or arsenate of lead (1½-50) Bordeaux mixture (5-5-50) | When plants are eight inches high As soon as beetle eggs hatch About July 1 |
| Raspberry and Blackberry | Anthraxose Gray bark disease (Spur blight) | Resin-bordeaux mixture | Before leaves open |
| Strawberry | Leaf blight | Bordeaux mixture (4-4-50) | Just before blossoms open |
| Tomato | Tomato worms Leaf mold Leaf spot Black rot | Arsenate of lead (1½-50) Bordeaux mixture (5-5-50) | When worms appear Just after the fruit sets |
| | Red spider Powdery mildew | Water or some tobacco decoction Potassium sulfide (Liver of sulfur) | As soon as first seen Whenever mildew appears |
| Sweet pea | Plant lice Mildew | Soap solution or nicofume liquid Potassium sulfide | As soon as noticed As soon as it appears |

Other spraying formulas can be had by writing to the Division of Entomology or the Division of Plant Pathology, University Farm, St. Paul, Minn.
 * Prepared in coöperation with Section of Tree Insects and Spraying, Division of Entomology.

CALENDAR

| SECOND SPRAYING | THIRD SPRAYING | REMARKS |
|---|--|--|
| Just after petals fall | July 1 When apple maggot is present two sprayings of arsenate of lead in July are necessary | Spraying just after the petals fall, getting as much of the liquid into the calyx cups as possible, is most effectual for codling moth. Make a fourth application, about 30 or 40 days after petals fall, if black rot or bitter rot is present. Destroy fallen leaves and all rotted fruit; prune out and burn all cankers; disinfect wounds. Trees should be thoroly covered. |
| A week or ten days later | | Spray every week or ten days until the middle of September. |
| Repeat when necessary | | The poison will stick better to the leaf if used in soapy water. With cauliflower, great care must be taken if the plant is heading. |
| Repeat when necessary | | Destroy diseased parts. If severe, dip plants in bordeaux or ammoniacal copper carbonate mixture before storing. |
| Repeat when necessary | | The adult insects do not seriously injure cucumbers in cold frames, nor do larvae under field conditions. |
| Repeat when necessary | | When berries begin to turn, use hellebore. |
| Keep leaves well covered | | Vines should be covered throughout season, especially during wet weather. |
| Repeat when necessary | | Same as for currant. When mildew is abundant, spray every ten or twelve days. |
| When fruit has set | Two weeks later | The leaves should be kept well covered with bordeaux mixture, especially during wet weather. |
| Every ten days to two weeks | | |
| When plums are size of small peas Bordeaux mixture (3-4-50 or lime-sulfur (1-40) as soon as blossom buds swell | When fruit begins to color | Destroy all mummies (shriveled fruit). Prune and burn affected branches in the fall. Destroy affected plums. |
| Repeat when necessary | | Vines should be well covered with bordeaux mixture throughout the season. This usually involves spraying every ten days or two weeks. |
| | | Cut out and burn diseased canes; keep old canes cut out. Protect with bordeaux mixture until canes are at least two-thirds grown. |
| After fruit is picked | | Cut off and destroy diseased leaves in fall or spring. |
| Repeat when necessary | | Vines should be well covered with bordeaux mixture throughout the season. Provide good ventilation. |
| Five or six days later | Ten days later | A flour paste made of 8 lbs. flour to 100 gals. water, added to the tobacco extract, is very effective. |
| Repeat when necessary | | Spray should be very fine and put on forcibly. A spray of water alone is often very effective. |

Never spray when trees are in full bloom.

In almost every case, an insecticide can be combined with a fungicide, and it pays to make the combination when possible.

